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AN ASSESSMENT OF AUTOMATIC SEWER FLOW SAMPLERS

Philip E. Shelley, et al

Hydrospace-Challenger, Incorporated

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AN ASSESSMENT OF AUTOMATIC SEWER FLOW SAMPLERS

by

Philip E. Shelley, Ph.D.
George A. Kirkpatrick, P.E.

Contract No. 68-03-0155

Project Officer

Richard Field, P.E., Chief
Storm and Combined Sewer Technology Branch
Edison Water Quality Research Laboratory
National Environmental Research Center - Cincinnati
Edison, New Jersey 08817

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A compendium of over 60 models of commercially available and custom designed automatic samplers is given with descriptions and characterizations of each unit presented along with an evaluation of its suitability for a storm and/or combined sewer application.

A review of field experience with automatic sampling equipment ~~is given~~ covering problems encountered and lessons learned. A technical assessment of the state-of-the-art in automatic sampler technology ~~is presented~~, and design guides for development of a new, improved automatic sampler for use in storm and combined sewers are ~~given~~ presented. (EPA)

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FOREWORD

Although the study was sponsored by the Storm and Combined Sewer Technology Branch and evaluation comments are made with such an application in mind, this report is much more general. It is hoped that it will be of interest and helpful to anyone with an automatic liquid sampling requirement, and that it can serve as a preliminary "shopper's guide".

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SECTION I

CONCLUSIONS

1. An automatic liquid sampler is one tool of several that must be employed for the characterization of a flow stream. Its selection must be based upon consideration of the overall sampling program to be undertaken, the characteristics of the flows to be sampled, the physical characteristics of the sampling sites, and the sample analyses that are available and desired.

2. In view of the large number of highly variable parameters associated with the storm and combined sewer application, no single automatic sampler can exist that is universally applicable with equal efficacy. Some requirements are conflicting, and a careful series of trade-off studies is required in order to arrive at a "best" selection for a particular program. Such a selection may not be well suited for a different program, and a systems approach is required for either the selection or design of automatic sampling equipment for storm and combined sewer application.

3. The proper selection of sampling sites can be as important as the selection of sampling methods and equipment. A clear understanding of the data requirements and ultimate use is necessary as is a familiarity with the sewer system to be examined.

4. Over 30 prospective manufacturers of automatic liquid sampling equipment were contacted. Although some omissions undoubtly have been made, it is felt that all major principles and techniques commercially available today have been included. These automatic samplers have been individually described and evaluated for application in a storm and/or combined sewer sampling program. Most of the units surveyed were not designed for such use, and many manufacturers do not recommend them for such applications.

5. Although certain commercially available automatic samplers may be suitable for certain storm and/or combined sewer sampling programs, no single unit appears eminently suitable for such an application. Improvements in intake design, sample intake and transport velocity, line sizes, and sample capacity appear warranted.

6. A number of custom designed, one-of-a-kind automatic samplers were reviewed and evaluated for application in a storm and/or combined sewer sampling program. Although some of these embodied fairly clever innovations, they were generally tailored around local peculiarities of the application site or program. None was deemed ideally suited for broad scale use as a storm or combined sewer sampling unit.

7. Field experience with automatic sampling equipment was reviewed with emphasis on recent EPA projects. Leaks in vacuum operated units; faulty automatic starters; inlet blockage and line plugging; limited suction lift; low transport velocities; complicated electrical systems; and failures of timers, micro-switches, relays and contacts, and reed switches were among the difficulties frequently encountered.

8. An assessment of the current state-of-the-art suggests that the technology is at hand to develop a new improved automatic sampler which will overcome many of the deficiencies of presently available commercial units.

9. One of the greatest problem areas is in the design of a sampler intake that can gather a representative sample, even in a stratified flow condition, and at the same time be relatively invulnerable to clogging or damage due to solids or debris in the flow stream.

SECTION II

RECOMMENDATIONS

1. No program to directly compare, in a side-by-side fashion, currently available commercial automatic sampling equipment has been conducted. It is recommended that such a comparison be made among some of the more promising portable commercial units.

2. It is recommended that the feasibility of making improvements over the use of standard commercial automatic sampling equipment in storm and combined sewers be demonstrated by the design, fabrication, and test of a new automatic sampler.

3. It is recommended that the development of a reliable flow height gage for use in storm and combined sewers be investigated. This could be used to provide a signal for starting the automatic sampler and, given the hydraulic parameters of the particular sewer in question, could be used to provide a flow meter function as well in certain cases.

4. The greatest deficiency in present day sampling equipment is in the design of the sampling intake. It is recommended that consideration be given to developing intakes that will yield more representative samples and at the same time be relatively invulnerable to clogging or damage by solids and debris in the flow stream.

SECTION III

INTRODUCTION

> "By a small sample we may judge of the whole."
>
> Cervantes (1605)

Since the very beginnings of primitive man's existence he has been faced with the necessity to sample, his first experiences probably being in the area of food and water selection. The need to sample arises from a data requirement that is necessary in order to make some judgmental decision and presumes the unavailability of the whole. If the data which are to be derived from the sample are to be efficacious in terms of the judgmental decision to be made, however, it is necessary that the sample be truly representative of the whole, at least in so far as those parameters which are of interest are concerned. It is this requirement, which arises from the nature of the data sought, that must be the overriding consideration in any sampling effort.

As the civilization of man continued, the exigencies of social awareness and community led to cooperative sampling and judgmental decisions affecting others as well as the sampler himself. In particular, man's requirement for water to maintain his existence and his concern for the quality of this water have partially shaped the course of history and given rise to more formal sampling programs for the common good. The records of ancient civilizations attest to the difficulties man has experienced in obtaining an adequate supply of water, protecting its quality, dealing with sediment transport in natural water courses, and the like. An excellent historical review of water sampling, especially as related to suspended sediment, is given in (1). Suffice it to note here that despite the fact that the first sampling for water quality is lost in the antiquity of man's development, it was not until the early part of the nineteenth century that documentation can be found of the formal sampling efforts of Gorsse and Subuors in the Rhone River in 1808 and 1809.

From such humble beginnings, reinforced by technology and man's increased awareness of his environment and his need to protect it, have arisen even more demanding requirements for water sampling programs and for equipment to carry them out. Today a large number of companies have been formed to produce sampling equipment, and it is to their products that much of the present report will be directed.

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PURPOSE AND SCOPE

This report is intended to present a current review of the state-of-the-art and assessment of sampling equipment and techniques. Particular emphasis has been placed on automatic liquid samplers which are commercially available today in the American marketplace. These are described and evaluated in terms of their suitability for use in storm or combined sewer applications. However, a sampling device which is suitable for such applications will most likely suffice for any other municipal waste water application as well. By collecting and presenting such a review it is hoped that shortcomings and limitations of these devices for such applications can be overcome and that this report can serve as a springboard for the development of new and/or improved devices. In order to assess the probable effectiveness of an existing device for sampling sewage in storm sewers and/or combined sewers, or to select criteria for the design of a new or improved device, consideration of the character of such sewers and sewage is essential. Questions to be considered are: What are their general characteristics? What are the usual flow modes found in such sewers? How do the pollutant materials carried in the sewers vary with time and location?

GENERAL CHARACTER OF SEWAGE

Knowledge of the character of the urban environment leads one to the expectation that stormwater draining from it will be of poor quality. Washings from the sidewalks, streets, alleys, and catch basins are a part of the runoff and include significant amounts of human and animal refuse. In industrial areas, chemicals, fertilizers, coal, ores, and other products are stockpiled exposed to rainfall, so that a significant quantity of these materials appears in the runoff. Extreme quantities of organic materials such as leaves and grass cuttings often appear in storm sewers. In the fall, such sewers at times become almost completely filled with leaves. Often during storms large boards, limbs, rock, and every imaginable kind of debris appear in the sewers, probably as a result of breaks in the sewers and/or accessory equipment designed to screen out the larger items. One of the heaviest pollution loads is that of eroded silts and sediments washed from the land surface. Much of this is from construction areas where the land has been disturbed prior to completion of streets and buildings and reestablishment of plant life. Finally, a significant amount of solids found in storm runoff originates as dustfall from air pollution. According to studies made in Chicago (2), about 3 percent of the total solids load has its source in dustfall.

General observation of the polluted nature of storm runoff from urban areas is supported by a number of studies made in several large cities in the United States, and in Oxney, England; Moscow and Leningrad, U.S.S.R., Stockholm, Sweden; and Pretoria, South Africa. In (2) the American Public Works Association states, "Stormwater runoff has been found in many instances to be akin to sanitary sewage in its pollutional characteristics and in a few instances some parameters of pollution are even greater". Table 1, which is taken from (5), contains selected data on the characteristics of urban stormwater.

In some areas, sewers classed as storm sewers are, in fact, sanitary or industrial waste sewers due to unauthorized and various other connections made to them. This condition may become so aggravated that a continuous flow of sanitary sewage flows into the receiving stream. Wastes from various commercial and industrial enterprises are often diverted to these so-called storm sewers. A rather common pollutant is the flushings from oil tanks.

Combined sewers are designed and constructed to carry both stormwater and sanitary sewage and/or industrial wastes. Therefore, sewage in them has all the pollutional aspects of storm runoff as described above, but also includes the pollution load of domestic wastes.

Where industrial wastes are contributed also, a very complex sewage, with respect to both varied flow rate and pollution load, is created. The task of sampling and analyzing this creation with reasonable accuracy becomes an extremely difficult one.

Because of normal leaks at joints, pipe breaks, loss of manhole covers, and other unplanned openings to them, separate sanitary sewers often carry large flows of storm runoff and/or infiltrate. This usually occurs in sections of high ground water level, or where the sewer line is constructed in, or adjacent to, a stream bed. Under such conditions, these sewers have much the same character as combined sewers, and require the same types of sampling equipment and methods.

FLOW MODES

Storm sewers, during periods of no rainfall, often carry a small but significant flow. This may be flow from ground water, or "base flow", which gains access to the sewer from unpaved stream courses. Such base flow may appear as runoff from parks or from suburban areas where there are open drains leading to the storm sewer.

TABLE 1. Characteristics of Urban Stormwater*

Characteristic	Range of Values
BOD_5 (mg/l)	1->700
COD (mg/l)	5-3,100
TSS (mg/l)	2-11,300
TS (mg/l)	450-14,600
Volatile TS (mg/l)	12-1,600
Settleable solids (ml/l)	0.5-5,400
Organic N (mg/l)	0.1-16
NH_3N (mg/l)	0.1-2.5
Soluble PO_4 (mg/l)	0.1-10
Total PO_4 (mg/l)	0.1-125
Chlorides (mg/l)	2-25,000†
Oils (mg/l)	0-110
Phenols (mg/l)	0-0.2
Lead (mg/l)	0-1.9
Total coliforms (no./100 ml)	200-146 x 10^6
Fecal coliforms (no./100 ml)	55-112 x 10^6
Fecal streptocci (no./100 ml)	200-1.2 x 10^6

* Taken from Reference 5.

† With highway deicing.

Unfortunately, much of the flow in storm sewers during periods of no rainfall is composed of domestic sewage and/or industrial wastes. Where municipal ordinances concerning connections to sewers are not rigidly enforced, it appears to be reasonably certain that unauthorized connections to storm sewers will appear. In some cases, the runoff from septic tanks is carried to them. Connections for the discharge of swimming pools, foundation drains, sump pumps, cooling water, and pretreated industrial process water to storm sewers are permitted in many municipalities, and contribute to flow during periods of no rainfall.

Storm runoff is the excess rainfall which runs off the ground surface after losses resulting from infiltration to ground water, evaporation, transpiration by vegetation, and ponding occur. A small portion of the rainfall is held in depression storage, resulting from small irregularities in the land surface. The quantity, or rate of flow, of such runoff varies with intensity, duration, and areal distribution of rainfall; character of the soil and plant life; season of the year; size, shape, and slope of drainage basin, and other factors. Ground seepage loss varies during the storm, becoming less as the ground absorbs the water. The period of time since the previous, or antecedent, rainfall significantly affects the storm runoff.

In general, storm runoff is intermittent in accordance with the rainfall pattern for the area. It is also highly variable from storm to storm and during a particular storm.

The design capacity of storm sewers is based on the flow due to a storm occurring, on the average, once in a selected number of years (recurrence interval). Usually a recurrence interval not greater than 10 years is selected for the design of underground storm sewers. As a result, the design capacity of the sewer is exceeded at comparatively frequent intervals, resulting in surcharging and flooding of the overlying surface.

Flow in combined sewers during periods of no rainfall is called dry-weather flow. This is the flow of sanitary sewage and/or industrial wastes, and often includes infiltrated ground water. As the sewer is designed, dry-weather flow generally includes only a small portion of the total sewer capacity, on the order of 10% in the larger sewer sizes. However, due to overloading in many rapidly developing areas, the dry-weather flow sometimes requires a much larger percentage of total capacity. The storm runoff portion of the flow in combined sewers is as described above for storm sewers. However, the design capacity for carrying storm runoff is probably less than is usually provided for storm sewers.

Sewers for intercepting dry-weather flow from a system of combined sewers for transport to a point for treatment or disposal have been designed for enough capacity to include a portion of the stormwater in the system. In the United States, this interceptor capacity ranges from two to four times the dry-weather flow. A weir or other regulating device controls the flow of sewage to the interceptor by diverting the flow above a pre-selected stage to an overflow line. The excess flows, or overflows, are carried to some external channel, such as a creek or river. Thus, raw sewage is carried to the streams with storm runoff during periods of rainfall.

VARIABILITY OF POLLUTANT CONCENTRATION

The pollutant concentration in storm and combined sewers is highly variable, both with respect to the time and with the position in the sewer cross-section. This is true during periods of no rainfall as well as during storm runoff periods, but usually to a lesser extent.

Variability with Time

Probably the most constant character of pollutants occurs in storm sewers when all flow is base flow derived from ground water. Because of the slow movement of water through the ground, changes in concentration of pollutants occur only during relatively long time periods. Where unauthorized connections of domestic sewage and industrial waste lines to storm sewers are found, rapid fluctuations of concentration with time may occur. The domestic sewage constituent varies with time of day, with season of the year, and probably over long-term periods. Industrial wastes vary with specific processes and industries. Very rapid changes may occur with plant shift changes and with process dynamics. Conditions on weekends and holidays may be very different from those on regular work days.

Observation and experience have demonstrated that the heaviest concentration of suspended solids during periods of storm runoff usually occurs during the early part of the storm. At this time, the stage is rising and accumulated dry-weather solid residue is being flushed from the sewers, and washed and eroded from the tributary land areas. As runoff recedes, the sewer and land area surfaces exposed to flow are reduced, the flow velocities which serve to flush and erode are decreased, and the more easily dislodged solids have been acted upon. Thus, suspended material is reduced in concentration. This pattern of variation may not be followed during a period of storm runoff which immediately follows a previous storm runoff period because the land surface and sewer lines are relatively clean.

Pollutants derived from point sources, such as those from stockpile drainage, vary at the sampling location with time of travel from the source to the point of observation. Maximum concentration may occur after the peak of storm runoff. It is conceivable that there would be no contribution from some point sources during a specific storm because of areal variation of rainfall in the basin.

The variability of concentration of pollutants in combined sewer dry-weather flow is similar to that of storm sewers having unauthorized connections of domestic sewage and/or industrial waste lines. The fluctuations in domestic sewage and industrial waste concentration are discussed above.

Variability with Position in the Sewer Cross-Section

Many factors influence the variability of composition with position in the sewer cross-section. Among them are:

(a) Turbulent flow (as opposed to laminar) which occurs at the velocities and with the boundary conditions found in sewers, particularly high during periods of storm runoff. A description of these two states of flow is given by Chow (3), as follows:

> "Depending on the effect of viscosity relative to inertia, the flow may be laminar, turbulent, or transitional. In laminar flow, the water particles appear to move in definite smooth paths, or streamlines, and infinitesimally thin layers of fluid seem to slide over adjacent layers. In turbulent flow, the water particles move in irregular paths which are neither smooth nor fixed but which in the aggregate still represent the forward motion of the entire stream."

(b) Varying velocities within the section, with higher velocities near the surface and lower velocities near the bottom. Average velocity in the vertical is at about

0.6 depth. Velocities are higher near the center of the pipe or conduit than near the outer boundaries. Such velocity distributions are generally characteristic of open-channel flow conditions, but are not valid when the sewer becomes surcharged.

(c) The tendency for flows transporting materials of different density, and having different temperatures, to remain separate from each other for quite some distance following their convergence.

(d) The fact that substances in solution may well behave independently of suspended particles. Little is known of the lateral dispersion of solutions in sewage. Conversions from solution to suspension, and the reverse, would occur under some conditions.

(e) Vertical drops, chutes, or hydraulic jumps a short distance upstream from the section which will produce violent turbulence, resulting in improved distribution of suspended solids in the cross-section.

Suspended solids heavier than water have their lowest concentrations near the surface, and the concentration increases with depth. Near the bottom of the sewer may occur a "bed load" composed almost entirely of heavier solids. This may "slide" along the bottom or, with insufficient flow velocity, may rest on the bottom. As the velocity and turbulence increase, the "bed load" may be picked up and suspended in the sewage.

At the beginning of storm runoff, as water picks up solids which have accumulated in the sewer upstream during periods of no rainfall, the flow may be composed largely of sewage solids, or "bed load", which appears to be pushed ahead by the water.

Suspended materials lighter than water, such as oils and greases, float on the surface, as do leaves, limbs, boards, bottles, and cloth and paper materials. Other small, light particles are moved randomly within the flow by turbulence. These may be well distributed in the cross-section without significant effect of variable velocity within the section.

Larger, heavier suspended and floating solids tend to move to the outside of a horizontal curve as a result of centrifugal inertia force. Particles with a specific gravity much less than 1.00 may tend to move toward the inside of the curve. Because the effect of curvature on flow often continues downstream a considerable distance, it is probable that a normal distribution of suspended matter is not found on a curve, or downstream for a distance of several sewer widths.

Incoming sewage from an upstream lateral with different density and temperature may not mix well, and often flows for long distances without combining with the main body of the sewer. The appearance may be of two streams flowing side-by-side, each with different quality characteristics. A sample taken from either stream is not representative of the entire stream character.

SECTION IV

REQUIREMENTS AND PURPOSES OF SAMPLING

Sampling of sewage is performed to satisfy various purposes and requirements. These include the planning, design and operation of facilities for the control and treatment of sewage; the enforcement of water quality standards and objectives; and general research to increase our knowledge of the characterization of sewage.

Development of a program of sampling is presently based on a limited number of properties and constituents for which analyses are made. The type of sample collected depends on the purpose of the program, and on both technical and economic considerations.

COMMON PROPERTIES AND CONSTITUENTS

Although the constituents of sewage include most substances known to man, there are a limited number of analyses made to determine the more common properties and constituents. Most of these are shown in Table 2, which is taken from (4) with the addition of bacteria and TOC parameters, and of the column on required sample sizes. Columns of the table provide information as follows:

Column 1 - Specific sewage parameter.

Column 2 - Preservative essential to sustaining the character of sewage as sampled between the time of sampling and the time of making the analysis.

Column 3 - The maximum period for holding the sample prior to the analysis. This is the allowable period after the preservative has been applied.

Column 4 - Approximate required sample size. This can be considered only a very rough figure to assist in designing a sampling program. In some cases there may be a difference in the size of sample required for a given parameter, depending on the method of analysis to be used.

Figures given for sample size are generally large. For example, much smaller samples are needed with use of various systems of automatic analysis. The Technicon Auto-Analyzer requires samples of less than 30 ml, and is recommended for total alkalinity, chloride, cyanide, fluoride, total hardness, nitrogen (ammonia), nitrogen (Kjeldahl), nitrogen (nitrate - nitrite), phosphorus, sulfate, COD, and others.

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TABLE 2. Properties and Constituents of Sewage

Parameter	Preservative	Maximum Holding Period	Approximate Required Sample Size (ml)
Acidity-Alkalinity	Refrigeration at 4°C	24 hours	50-100
Biochemical Oxygen Demand (5-day)	Refrigeration at 4°C	6 hours	1000
Calcium	None Required	Indefinite	50
Chemical Oxygen Demand	2 ml H_2SO_4 per liter	7 days	50
Chloride	None Required	Indefinite	50
Bacteria - fecal coliform, total coliform, or fecal streptococcus	Maintain temperature as at source - usually requires refrigeration	6 hours	200
Color	Refrigeration at 4°C	24 hours	50
Cyanide	NaOH to pH 10	24 hours	500
Dissolved Oxygen	Determine on site	No holding	250-300
Fluoride	None Required	7 days	200-300
Hardness	None Required	7 days	25
*Metals, Total	5 ml HNO_3 per liter	6 months	100
**Metals, Dissolved	Filtrate: 3 ml 1:1 HNO_3 per liter	6 months	100
Nitrogen, Ammonia	40 mg $HgCl_2$ per liter - 4°C	7 days	100
Nitrogen, Kjeldahl	40 mg $HgCl_2$ per liter - 4°C	Unstable	100
Nitrogen, Nitrate - Nitrite	40 mg $HgCl_2$ per liter - 4°C	7 days	100
Oil and Grease	2 ml H_2SO_4 per liter - 4°C	24 hours	1000
Organic Carbon (Total and Dissolved)	2 ml H_2SO_4 per liter (pH 2)	7 days	100
pH	Determine on site	No holding	--
Phenolics	1.0 g $CuSO_{4/1}$ + H_3PO_4 to pH 4.0 - 4°C	24 hours	500
Phosphorus	40 mg $HgCl_2$ per liter - 4°C	7 days	200
Solids (total, dissolved, suspended, volatile)	None Available	7 days	1000
Specific Conductance	None Required	7 days	--
Sulfate	Refrigeration at 4°C	7 days	100
Sulfide	2 ml Zn acetate per liter	7 days	1000
Threshold Odor	Refrigeration at 4°C	24 hours	200
Turbidity	None Available	7 days	1000

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* Sum of the concentrations of metals in both the dissolved and suspended fractions.

** For determination of trace metals in solution by atomic absorption spectroscopy.

TYPE OF SAMPLE

The type of sample collected depends on a number of factors such as the rate of change of flow and of the character of the sewage, the accuracy required, and the availability of funds for conducting the sampling program. All samples collected, either manually or with automatic equipment, are included in the following types:

1. Manual "grab" samples which are obtained by dipping a container into the sewer and bringing up a sample of wastewater. Containers are sometimes devised to grab a sample at a stationary depth or so that a sample integrated from bottom to top of the stream is collected. Water flows gradually into the container as it passed through the flow.

2. Automatic "grab", or discrete, samples which are collected at selected intervals, and each sample is retained separately for analysis. Usually each sample is collected at a single point in the sewer cross-section. However, in a few instances samplers with multiple ports have been used to allow simultaneous collection from several points in the cross-section.

3. Simple composite samples, which are made up of a series of smaller samples (aliquots) of constant volume collected at regular time intervals and combined in a single container. The series of samples is collected over a selected time period, such as 24 hours, or during a period of storm runoff, for example. The simple composite represents the average condition of the waste during the period only if the flow is constant.

4. Flow-proportional composite samples, which are collected in relation to the flow volume during the period of compositing, thus indicating the "average" waste condition during the period. One of two ways of accomplishing this is to collect samples of equal volume, but at time intervals which are inversely proportional to the volume of flow. That is, the time interval between samples is reduced as the volume of flow increases, and a greater total sample volume is collected. Flow proportioning can also be achieved by increasing the volume of

each sample collected in proportion to the flow, but keeping the time interval between samples constant.

5. Manually composited samples which are obtained, where recording flow records are available, from fixed volume "grab", or discrete, samples collected at known times and proportioned manually to produce a flow proportioned composite sample.

6. Sequential composite samples, which are composed of a series of short-period composites, each of which is held in an individual container. For example, each of several samples collected during a 1-hour period may be composited for the hour. The 24-hour sequential composite is made up from the individual 1-hour composites.

ADEQUACY OF A SAMPLING PROGRAM

The adequacy of a sampling program depends largely on the optimum selection of sampling sites. Both the program cost and its effectiveness in collecting samples representative of the character of sewer flows are seriously affected by the care exercised in site selection. Similarly, the kinds of samplers selected determine the adequacy of the program with respect to obtaining suitable data for the needs of the particular sampling program.

In most cases, use of mathematical statistical analysis for determining the probable errors in the data obtained by sewer sampling is not practical. A single "grab" sample of 1 liter, even in dry-weather flows, is not necessarily indicative of the average character of the flow. With respect to an instant of time, the indicated character of the sewage may vary with the point in the cross-section from which it was "grabbed". One must consider the universe of sewage volumes represented by the sample. At the instant of sampling, it may be all the liters of sewage in the cross-section at that instant. But, if the sewage is not thoroughly mixed, we know that the sample is biased, that is, it may represent only a portion of the 1-liter samples in the cross-section, possibly only those near the surface of the flow.

In periods of storm runoff, it is known, if only by observation, that the character of the sewage is continually changing, possibly with great rapidity. There then becomes no single universe represented by the "grab" sample. Instead, there is an infinite number of universes, and the single "grab" sample is without meaning in determining the character of the sewage. A similar situation exists in the case of sewers carrying industrial wastes. The variability of flow and of quality parameters during periods of storm runoff are illustrated in figure 1, wherein quantity and quality data for a storm on the Bloody Run sewer watershed at Cincinnati, Ohio, are graphically presented.

It becomes apparent, then, that a large number of samples is required to adequately characterize the character of sewage in a combined sewer during and immediately after a storm event, particularly if the character is to be related to flow rate. Compositing the samples in proportion to flow rate may determine the average character of the sewage during the period of compositing. However, it does nothing to describe the pattern of changes which may occur during that period.

Awareness of the general character of sewer flows and of flow modes in storm sewers and combined sewers, and knowledge of the variability of pollutant concentration, leads to an understanding of how best to select sites for sampling. Some of the considerations in making such selections are:

1. Maximum accessibility and safety -- Manholes on busy streets should be avoided if possible; shallow depths with manhole steps in good condition are desirable. Sites with a history of surcharging and/or submergence by surface water should be avoided if possible. Avoid locations which may tend to invite vandalism.

2. Be sure that the site provides the information desired -- Familiarity with the sewer system is necessary. Knowledge of the existence of inflow or outflow between the sampling point and point of data use is essential.

3. Make certain the site is far enough downstream from tributary inflow to ensure mixing of the tributary with the main sewer.

4. Locate in a straight length of sewer, at least six sewer widths below bends.

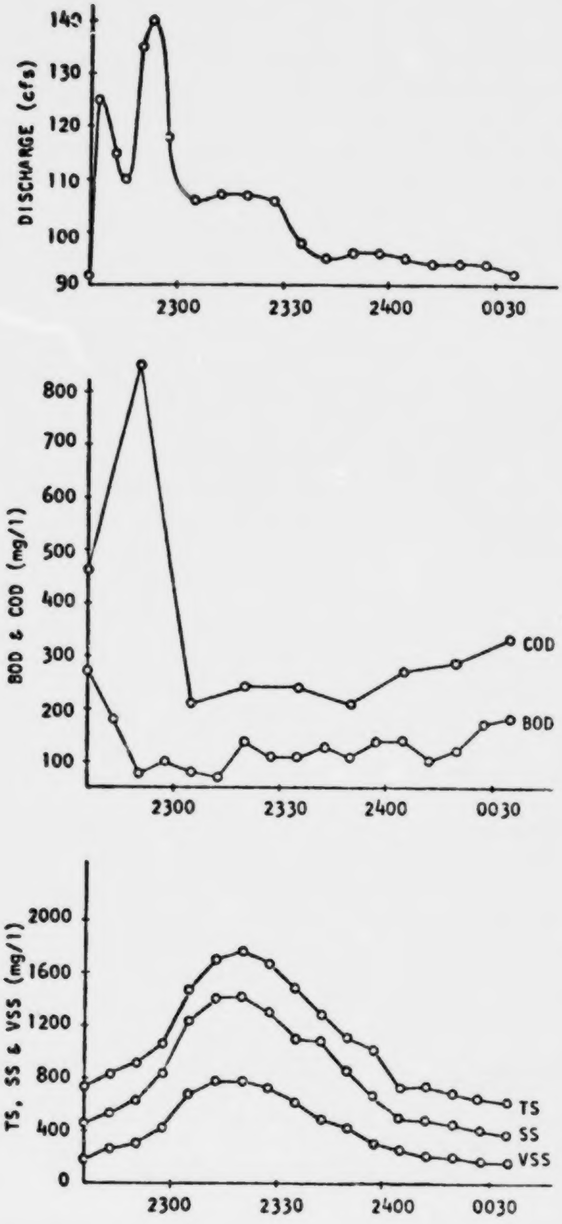

Figure 1. Runoff Quantity and Quality Data, Bloody Run Sewer Watershed*

* Taken from Reference 17.

5. Locate at a point of maximum turbulence, as found in sewer sections of greater roughness and of probable higher velocities. Locate just downstream from a drop or hydraulic jump, if possible.

6. In all cases, consider the cost of installation, balancing cost against effectiveness in providing the data needed.

Presently available sewage samplers have a great variety of characteristics with respect to size of sample collected, lift capability, type of sample collected (discrete or composite), material of construction, and numerous other both good and poor features. A number of considerations in selection of a sampler are:

1. Rate of change of sewage conditions
2. Frequency of change of sewage conditions
3. Range of sewage conditions
4. Periodicity or randomness of change
5. Availability of recorded flow data
6. Need for determining instantaneous conditions, average conditions, or both
7. Volume of sample required
8. Need for preservation of sample
9. Estimated size of suspended matter
10. Need for automatic controls for starting and stopping
11. Need for mobility or for a permanent installation
12. Operating head requirements.

Because of the variability in the character of storm and/or combined sewage, and because of the many physical difficulties in collecting samples to characterize the sewage, precise characterization is not practicable, nor is it possible. In recognition of this fact, one must guard against embarking on an excessively detailed sampling program, thus increasing costs, both for sampling and for analyzing the samples, beyond costs that can be considered sufficient for conducting a program which is adequate for the intended purpose.

A careful study of costs should be made prior to commencing a program of sampling, balancing cost against the number of samples and analyses required for adequate characterization of the wastewater. As the program progresses, current study of the results being obtained may make it reasonable to reduce or increase the number of samples collected.

The unit cost of handling and analyzing samples can often be reduced by careful planning and scheduling of field work, and by coordination with laboratory requirements. If the volume of samples is large, and the program is to continue over a long time period, consideration should be given to use of equipment for automatic analyses and in-situ monitoring. A number of equipment types and methods, such as specific ion electrodes and probes, are available for these purposes. As an example, approximately 15 samples per hour can be analyzed for chloride, using the Technicon Auto-Analyzer. Samples of only 4 ml volume are required. Caution is needed in selecting equipment suitable for a series of parameters for which analyses are to be made. With some equipment, the time required for making necessary adjustments between each of a series of tests may counteract the rapidity of making analyses for a single parameter.

SPECIFIC SAMPLING PURPOSES AND REQUIREMENTS

Sampling programs are set up for various purposes for which the requirements are not necessarily the same. That is, parameters important to one kind of project may not be needed for another project having a different objective. As an example, parameters of interest for operation of facilities for control and treatment of stormwater and/or combined sewage may be more limited in number than those needed for planning and design of the facilities. In the operation stage, experience at the particular location and with the unique facilities, may have demonstrated a more limited sampling need. On the other hand, where stormwater is combined with industrial wastes, analyses for additional parameters may be required.

A number of physical, chemical, combinations of physical-chemical, and biological methods have been considered in the Storm and Combined Sewer Pollution Control Program of the EPA for treatment of stormwater and combined sewage. In most cases, some type of control such as reduction of instantaneous peak flows is essential for practical application of treatment methods. These include storage facilities of many types, flow regulation and routing, and remote flow and overflow sensing and telemetering.

Specific processes which have been investigated are (5):

Physical - (1) Fine mesh screening; (2) Microstrainer; (3) Screening/Dissolved-air flotation; (4) High-rate single-, dual, or tri-media filtration; (5) Swirl and helical separation; (6) Tube settlers; etc.

Chemical - (1) Coagulant and polyelectrolyte aids for sedimentation, filtration, flotation and microstraining; (2) Chemical oxidation and use of ozone for oxidation; and (3) Disinfection -- chlorination, ozonation, high rate application, on-site generation, and use of combined halogens (chlorine and iodine) and chlorine dioxide.

Physical-Chemical - (1) Screening plus dissolved-air flotation with flotation aids; (2) Screening - chemical flocculation - sedimentation - high-rate filtration; (3) Powdered and granular activated carbon adsorption; (4) Chemical flocculation - tube sedimentation - tri-media filtration; and (5) Screening - coagulation - high rate dual-media filtration.

Biological - (1) High-rate plastic and rock media trickling filters; (2) Bio-adsorption (contact stabilization); (3) Stabilization ponds; (4) Rotating biological contactor; and (5) Deep-tank aerobic and anaerobic treatment.

For planning and designing such facilities and processes, and for testing their impact on receiving streams, sampling for certain basic wastewater parameters is essential. In general these include:

1. Biochemical oxygen demand (BOD) - Used to determine the relative oxygen requirement of the wastewater. Data from BOD tests are used for the development of engineering criteria for the design of wastewater treatment plants.
2. Chemical oxygen demand (COD) - Provides additional information concerning the oxygen requirement of wastewater. It provides an independent measurement of organic matter in

the sample, rather than being a substitute for the BOD test. For combined sewer overflows and stormwater, COD may be more representative of oxygen demand in a receiving stream because of the presence of metals and other toxicants which are relatively non-biodegradable.

3. Total oxygen demand (TOD) - A recently developed test to measure the organic content of wastewater in which the organics are converted to stable end products in a platinum-catalyzed combustion chamber. The test can be performed quickly, and results have been correlated with the COD in certain locations.

4. Total organic carbon (TOC) - Still another means of measuring the organic matter present in water which has found increasing use in recent times. The test is especially applicable to small concentrations of organic matter.

5. Chloride - One of the major anions in water and sewage. The concentration in sewage may be increased by some industrial wastes, by runoff from streets and highways where salt is used to control ice formation, salt water intrusion in tidal areas, etc. A high chloride content is injurious to vehicles and highway structures, and may contaminate water supplies near the highway.

6. Nitrogen Series - A product of microbiologic activity, is an indicator of sewage pollution, or pollution resulting from fertilizers, automobile exhausts, or other sources. Its presence may require additional amounts of chlorine, or introduction of a nitrogen fixation process, in order to produce a free chlorine residual in control of bacteria.

7. pH - The logarithm of the reciprocal of hydrogen ion activity. State regulations often prescribe pH limits for effluents from industrial waste treatment plants. Provides a control in chemical and biological treatment processes for wastewater.

8. Solids (Total, Suspended, Volatile, and Settleable) - Usually represent a large fraction of the pollutional load in combined sewage. Inorganic sediments, in a physical sense, are major pollutants, but also serve as the transporting or catalytic agents that may either expand or reduce the severity of other forms of pollution (6).

9. Oil and Grease - Commonly found in sanitary sewage, but also appear in industrial wastes as a result of various industrial processes. Present a serious problem of removal in wastewater treatment facilities.

10. Bacterial Indicators (Total Coliform, Fecal Coliform, Fecal Streptococcus) - Indicate the level of bacterial contamination.

Where more exotic wastes are combined with stormwater and sanitary sewage, additional treatment facilities may be required for the removal of industrial byproducts and nutrients such as cyanide, fluoride, metals, pesticides, nitrogen, phosphorus, sulfate and sulfide. For planning and design of such treatment facilites, additional analyses are required in accordance with the pollutant material expected in the wastewater. This may, in turn, require significant expansion of the sampling program.

Sampling and analyses of wastewater are necessary to the satisfactory operation of treatment plants. Pollutants in the incoming storm sewer or combined sewer are compared with those in the effluent from the treatment plant to determine the effectiveness of the treatment process. Additionally, sampling of the receiving stream before and after treatment/control system installation indicates the benefits gained from the installation. Knowledge of the concentration of pollutants entering the plant can be used also to make adjustments to the treatment process as required. Continuous monitoring of the stream below the treatment/control facility is important to facility operation. Depending on the type or types of treatment process used, the number of parameters required for sampling and analyses is usually less than those required for planning and design. For example, where treatment consists only of sedimentation and chlorination, analyses for oxygen demand, suspended solids, bacterial indicators, and for chlorine residual may be sufficient. If chemicals are used to assist the sedimentation process, determination of pH may be needed. The sampling program can be determined largely in accordance with previous experience and knowledge of the pollutants found.

Sampling programs should start long before installation of combined sewer overflow and stormwater treatment/control facilities to establish the objectives of the facilities and to provide necessary design and operation criteria. A much longer time period for sampling may be required than anticipated because of the need to sample during periods of storm runoff, which may be few in drought years.

In some cases, the availability of historical quality data may provide a basis for prediction of future character for planning and design purposes. Dependence on such predicted data is not sufficient, and collection of current data is required to verify predictions and, later, to measure facility effectiveness.

Programs of sampling and analyses of wastewater in storm and/or combined sewers are frequently used for the enforcement of water quality standards or objectives. Such programs provide information leading to the source of various types of pollution. Often, the wastewater is continually monitored to check on compliance with pollution control laws and regulations. The range of different parameters to be measured for these purposes is continually expanding with the development of new processes. There appears to be no limit to future analytical requirements.

SECTION V

DESIRABLE EQUIPMENT CHARACTERISTICS

Having reviewed some of the vagaries of the storm and combined sewer sampling problem in the preceding sections, it is intuitively obvious that a single piece of equipment cannot exist that is ideal for all sampling programs in all storm and combined sewer flows of interest. One can, however, set down some general requirements for sampling equipment that is to be used in the storm or combined sewer application.

EQUIPMENT REQUIREMENTS

The success of an automatic sampler in gathering a representative sample starts with the design of the sampler intake. This obviously will be dependent upon conditions at the particular site where the sample is to be extracted. If one is fortunate enough to have a situation where the sewer flow is homogeneous with respect to the parameters being sampled, then a simple single point of extraction for the sample will be adequate. In the more typical case, however, there is a spatial variation in the concentration of the particular constituent that is to be examined as part of a sampling program, and then the sampling intake must be designed so that the sample which is gathered will be nearly representative of the actual flow. Several different designs have been utilized in an attempt to meet this objective. However, none can be considered as ideal or universally applicable. In a rather comprehensive study reported in (7), the characteristics of the sampler orifice geometry were examined with particular regard to the ability of the sampler to gather a representative sample of suspended solids. Among parameters varied were size of orifice, shape of orifice and intake velocity. All orifices were located in a vertical plate forming part of the wall of the test section of the flume which was used for this study. The sample flow was therefore extracted at right angles to the stream flow. The major conclusion that was reached by the investigators was that, as far as suspended solids were concerned, the geometry of the orifice at most played a secondary role and that the most representative samples were obtained when the sampler intake tube velocity was equal to the free stream velocity. In situations where flow velocity gradients are strongly present, this observation must be taken into account in the design of a proper sampler intake.

The automatic sampler must be capable of lifting the sample to a sufficient height to allow its utilization over a rather wide range of operating heads. It would appear that a minimum sample lift of 15 feet or so is almost mandatory in order to give a fairly wide range of applicability. It is also important that the sample size not be a function of the sample lift; that is, the sample size should not become significantly less as the sample lift increases.

The sample line size must be large enough to give assurances that there will be no plugging or clogging anywhere within the sampling train. However, the line size must also be small enough so that complete transport of suspended solids is assured. Obviously, the velocities in any vertical section of the sampling train must well exceed the settling velocity of the maximum size particle that is to be sampled. Thus, the sample flow rate and line size are connected and must be approached together from design considerations.

The sample capacity that is designed into the piece of equipment will depend upon the subsequent analyses that the sample is to be subjected to and the volumetric requirements for conducting these analyses. However, in general, it is desirable to have a fairly large quantity of material on hand, it being safer to err on the side of collecting too much rather than too little. As a minimum, it would seem that at least a pint and preferably a liter of fluid would be desirable for any discrete sample. For composite samples at least a gallon and preferably two (4 to 8 liters) should be collected.

The controls on the automatic sampler should allow some degree of freedom in the operation and utilization of the particular piece of equipment. A built-in timer is desirable to allow preprogrammed operation of the equipment. Such operation would be particularly useful, for example, in characterizing the buildup of pollutants in the early stages of storm runoff. However, the equipment should also be capable of taking signals from some flow measuring device so that flow proportional operation can be realized. It is also desirable that the equipment be able to start up automatically upon signal from some external device that might indicate the onset of storm flow phenomena such as an external rain gauge, flow height gauge, etc. Flexibility in operation is very desirable.

A power source will be required for any automatic sampler. It may take the form of a battery pack or clock type spring motor that is integral to the sampler itself. It may be pressurized gas, air pressurized from an external source, or electrical power, depending upon the availability at the site.

In addition to being able to gather a representative sample from the flow, the sampling equipment must also be capable of transporting the sample without pre-contamination or cross-contamination from earlier samples or aliquots and of storing the gathered sample in some suitable way. As was noted in section IV, chemical preservation is required for certain parameters that may be subject to later analyses, but refrigeration of the sample is also required and is stated as the best single means of preservation.

DESIRABLE FEATURES

In addition to the foregoing requirements of automatic sampling equipment, there are also certain desirable features which will enhance the utility and value of the equipment. For example, the design should be such that maintenance and troubleshooting are relatively simple tasks. Spare parts should be readily available and reasonably priced. The equipment design should be such that the unit has maximum inherent reliability. As a general rule, complexity in design should be avoided even at the sacrifice of a certain degree of flexibility of operation. A reliable unit that gathers a reasonably representative sample most of the time is much more desirable than an extremely sophisticated complex unit that gathers a very representative sample 10 percent of the time, the other 90 percent of the time being spent undergoing some form of repair due to a malfunction associated with its complexity.

It is also desirable that the cost of the equipment be as low as practical both in terms of acquisition as well as operational and maintenance costs. For example, a piece of equipment that requires 100 man-hours to clean after each 24 hours of operation is very undesirable. It is also desirable that the unit be capable of unattended operation and remaining in a standby condition for extended periods of time.

The sampler should be of sturdy construction with a minimum of parts exposed to the sewage or to the highly humid, corrosive atmosphere associated directly with the sewer. It should not be subject to corrosion or the possiblity of sample contamination due to its materials of construction. The sample containers should be capable of being easily removed and cleaned; preferably they should be disposable.

PROBLEM AREAS

The sampler by its design must have a maximum probability of successful operation in the very hostile storm and combined sewer environment. It should offer every reasonable protection against obstruction or clogging of the sampling ports and, within the sampler itself, of the sampling train. It is in a very vulnerable position if it offers any significant obstruction to the flow because of the large debris which are sometimes found in such waters. The unit must be capable of operation under the full range of flow conditions which are peculiar to storm and combined sewers and this operation should be unimpeded by the movement of solids within the fluid flow. If the unit is to be designed for operation in a manhole, it almost certainly should be capable of total immersion or flooding during adverse storm conditions which very frequently cause surcharging in many manhole areas. It is also necessary that the unit be able to withstand and operate under freezing ambient conditions, and that it be able to withstand the high flow velocities and the associated high momentums found in storm and combined sewer flows.

Probably one of the most significant problem areas lies in the attempt to gather a sample that is representative of low as well as high specific gravity suspended solids. The different momentum characteristics call for differing approaches in sampler intake design and in intake velocities. Another problem area arises in a sampling program where it is desirable to sample floatable solids and materials such as oils and greases as well as very coarse bottom solids and bed load proper.

For samples which are to be analyzed for constituents which require chemical fixing soon after the sample is collected, there are other problems. Although it is true that the required amount of fixing agent could be placed in the sample container prior to placing it in the field, for composite samples in particular, where the eventual total sample is built up of smaller aliquots gathered over an extended period of time, the initial high concentrations of the fixing agent as it becomes mixed with the early aliquots may well be such as to render the entire sample unsuitable for its intended purpose.

The precision of the analyses that the sample is to be subjected to should also be kept in mind by the designer of the equipment. For example, in (4) it is noted that 77 analysts in 53 laboratories analyzed natural water samples plus an exact increment of biodegradable organic compounds. At a mean value of 194 milligrams per liter BOD, the standard deviation was plus or minus 40 milligrams per liter. This points out again the need for the designer to look at the left as well as the right of the decimal point.

Adsorption of certain pollutants by materials of the sampler train or sample container may result in a non-representative sample.

SECTION VI

REVIEW OF COMMERCIALLY AVAILABLE AUTOMATIC SAMPLERS

INTRODUCTION

Although some types of automatic liquid sampling equipment have been available commercially for some time, project engineers continue to design custom sampling units for their particular projects due to a lack of commercial availability of suitable equipment. In the last few years, however, there has been a proliferation of commercial sampling equipment designed for various applications. In the present survey, after a preliminary screening, over 30 prospective sampler manufacturers were contacted. Although a few of these companies were no longer in business, it was much more typical that new companies were being formed and existing companies were adding automatic sampling equipment to their product lines. In addition to their standard product lines, most manufacturers of automatic sampling equipment provide special adaptations of their equipment or custom designs to meet unique requirements of certain projects. Some designs which began in this way have become standard products, and this can be expected to continue.

The products themselves are rapidly changing also. Not only are improvements being made as field experience is gathered with new designs, but attention is also being paid to certain areas that have heretofore been largely ignored. For example, one company is introducing sampling probes that allow gathering oil or various other liquids from the flow surface, and the like.

In view of the burgeoning nature of this product area, it is inevitable that some ommissions have been made. Obviously, it would be presumptive to state that this survey is complete in every detail. For example, one company that was contacted expects to expand its product line from about 15 models to over 30 models in the near future.

In order to facilitate the reader's comparison of the over 50 models of automatic samplers that are presented, a common format has been designed. A few words about the headings of this format are in order.

Designation:	Identifies the particular sampler model that is being considered. In some instances several models are described under the same general

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heading. This occurs when there does not appear to be a fundamental difference in the basic principles of operation but rather the manufacturer has chosen to give separate designations based upon the addition of certain features such as refrigeration, a weather-proof case, etc.

Manufacturer:	Lists the company that supplies the particular model in question, its address, and its telephone number.
Sampler Intake:	Describes the part of the sampler that actually extracts fluid from the stream being sampled. It may be, for example, a supplied custom designed intake probe, a dipping bucket or scoop, etc. However, many of the samplers do not provide any form of intake other than the end of a tube through which a sample is to be transported to the equipment.
Gathering Method:	Addresses the method for gathering the sample and transporting it to its container. Three basic categories are identified: Mechanical, where dippers, scoops, etc. are utilized; Suction Lift, employing either evacuated vessels, vacuum pump, or mechanical pump; and Forced Flow, utilizing pneumatic ejection, a submerged pump, etc.
Sample Lift:	Addresses the maximum practical vertical lift that the particular piece of equipment is capable of in operation.
Line Size:	Describes the minimum line diameter of the sampling train wherever it may occur in the particular piece of equipment. Due to the presence of tube fittings, screens, valves, etc. in some designs, it does not necessarily represent maximum particle size.

Sample Flow Rate:	Gives the flow rate of the sample as it is being transported within the sampling train of the piece of equipment in question.
Sample Capacity:	Addresses the size of the sample that is being collected. In the case of composite samplers, the aliquot size is also given.
Controls:	Addresses those controls within the sampler that can be utilized to vary its method of operation. For example, built-in timers, inputs from external flowmeters, etc.
Power Source:	Gives power source or sources that may be utilized to operate the equipment.
Sample Refrigerator:	Addresses the type of cooling that may be available to provide protection to collected samples.
Construction Materials:	Primary attention here has been devoted to the sampling train proper, although certain other materials such as case construction are also noted.
Basic Dimensions:	The overall package is described here in order to give the reader a general feel for the size of the unit. For those units which might be considered portable, a weight is also given. For units that are designed for fixed installations only, this fact is also noted.
Base Price:	The base price as quoted and effective in August 1972 is given here. Certain options or accessories that may be of general interest are also included with their prices.
General Comments:	Here any additional comments that are felt to be pertinent to the particular piece of equipment in question are given. This includes any additional descriptions that

are felt necessary in order to understand better the operating principles that are involved. Also included are certain performance claims that may be made by the manufacturer.

In general, the commercially available automatic samplers have been designed for a particular type of application. In the present work, however, they are being considered for application in a storm or combined sewer setting. Because of the vagaries of such an application as outlined in sections III and IV of this report, it is altogether possible that a particular unit may be quite well suited for one particular application and totally unsuitable for use in another. It is not the intention of this report to endorse any particular piece of equipment. Rather, they are being compared and evaluated for their suitability in general in a storm or combined sewer application. This evaluation takes the form of 12 points which are addressed for each model sampler that has been considered. They are the following:

1. Vulnerability to obstruction or clogging of sampling ports, tubes and pumps.

2. Obstruction of main stream flow and susceptibility to damage.

3. Operation under the full range of flow conditions peculiar to storm and combined sewers.

4. Operation unimpeded by the movement of solids such as silt, sand, gravel and debris within the fluid flow; including durability.

5. Automatic start-up and operation (during storm conditions), unattended, self-cleaning.

6. Flexibility of operation allowed by control system.

7. Collection of samples of floatable materials, oils and grease, as well as coarser bottom solids.

8. Storage, maintenance and protection of collected samples from damage and deterioration as well as freedom of the sample train and containers from precontamination, adsorption, etc.

9. Amenability to installation and operation in confined and moisture laden places such as sewer manholes.

10. Ability to withstand total immersion or flooding during adverse flow conditions.

11. Ability to withstand and operate under freezing ambient conditions.

12. Ability to sample over a wide range of operating head conditions.

DESCRIPTIVE FORMS AND EVALUATIONS

The descriptive forms and evaluations, as discussed above, are presented in the following pages for various commercially available automatic samplers. The arrangement is alphabetical, and an index is provided on pages viii and ix.

Designation:	BIF SANITROL FLOW-RATIO MODEL 41
Manufacturer:	BIF Sanitrol P.O. Box 41 Largo, Florida 33540 Phone (813) 584-2157
Sampler Intake:	Dipping bucket
Gathering Method:	Mechanical; dipper on sprocket-chain drive.
Sample Lift:	16 inches to 16 feet
Line Size:	1" O.D. tube connects collection funnel to sample container.
Sample Flow Rate:	Not applicable
Sample Capacity:	Dipping bucket holds 1 ounce; user supplies sample composite container to suit.
Controls:	Sampling cycle can either be started at fixed, selected intervals from a built-in timer (15, 7.5, 3.75, or 1.88 minutes) or in response to signals from an external flow meter.
Power Source:	115V ac
Sample Refrigerator:	Separate automatic refrigerated sample compartment with two 1-gallon jugs available.
Construction Materials:	Dipper and funnel are stainless steel; sprockets and chain are stainless steel; enclosure is fiberglass.
Basic Dimensions:	Upper portion is 9 3/8"W x 9 1/4"D x 8"H; lower portion is 9 3/8"W x 4"D; fixed installation.
Base Price:	$545 with 16" mild steel chain plus $40 per foot for additional length. $595 with 16" stainless steel chain plus $50 per foot for additional length.

Figure 2. BIF Sanitrol Flow - Ratio Model 41 Sampler

Photograph courtesy of BIF Sanitrol.

General Comments:	Manufacturer states unit was designed to sample raw or effluent wastes. A heavy duty model is available for applications where mixed wastes are present such as a paper mill where wood chips and fiber are present in waste liquid.

BIF Sanitrol Flow-Ratio Model 41 Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket line is vulnerable to jamming by rags, debris, etc.
2. Unit provides a rigid obstruction to flow.
3. Unit should operate over full range of flows.
4. Movement of solids could jam unit.
5. No automatic starter; no self cleaning features.
6. Collects fixed size aliquots paced by built-in timer and composits them in a suitable container.
7. Does not appear well suited for collecting either floatables or coarser bottom solids.
8. No sample collector provided. Optional refrigerated sample container is available.
9. Unit is capable of manhole operation.
10. Unit cannot withstand total immersion.
11. Unit is not suitable for prolonged operation in freezing ambients.
12. 16 foot maximum lift puts some restriction on operating head conditions.

Designation:	**BRAILSFORD MODEL DC-F**
Manufacturer:	Brailsford and Company, Inc. Milton Road Rye, New York 10580 Phone (914) 967-1820
Sampler Intake:	End of 6 foot long sampling tube; weighted and fitted with 50 mesh strainer.
Gathering Method:	Suction lift by positive displacement pump.
Sample Lift:	Pump is capable of 10 foot lift but manufacturer recommends that lift be restricted to 3 to 7 feet.
Line Size:	Appears to be 1/4" I.D.
Sample Flow Rate:	Adjustable from about 0.1 to 0.6 cubic inches per minute.
Sample Capacity:	Pump output is collected in a 2-gallon jug.
Controls:	Pump stroke is adjustable by means of a slotted yoke on the piston rod. On/Off Switch.
Power Source:	6V dc dry cell battery
Sample Refrigerator:	None
Construction Materials:	Stainless steel, teflon, vinyl, polyethylene; case is laminated Formica-wood construction, plastic rain boot.
Basic Dimensions:	12"W x 9 1/2"H; weighs 19 pounds empty; portable.
Base Price;	$281.
General Comments:	Pump is valveless oscillating cylinder type. No lubrication is required for the life of the unit. Driven by a brushless dc motor of patented design with a service life

in excess of 3,000 hours. Continuous running pump is automatically shut off when sample jug is full.

A Model DU-1 is also available at $325. It is essentially a Model DC-F with the addition of an electric timer, wherein the pumping rate can be set for any designed frequency between one revolution every 1.5 minutes and one revolution every 12 minutes. Model EP is a similar unit but explosion proof at $330.

Brailsford Model DC-F Evaluation

1. 50 mesh strainer on end of sampling tube might be prone to clogging.
2. Minimal obstruction of flow.
3. Should operate reasonably well under all flow conditions, but low intake velocity will affect representativeness of sample at high flow rates.
4. Movement of solids should not hamper operation.
5. Continuous flow unit, no automatic starter, no other self cleaning features.
6. Unit collects a continuous, low flow rate stream of sample and composits it in a 2-gallon jug.
7. Unsuitable for collection of floatables or coarser bottom solids.
8. No refrigerator. Continuous flow eliminates cross contamination.
9. Appears fairly well suited for manhole operation.
10. Cannot withstand immersion.
11. Not suited for operation in freezing ambients.
12. Recommended lift of 4 feet puts restriction on use of unit.

Designation:	BRAILSFORD MODEL EV
Manufacturer:	Brailsford and Company, Inc. Milton Road Rye, New York 10580 Phone (914) 967-1820
Sampler Intake:	End of 6 foot long sampling tube fitted with a molded plastic inlet scoop-strainer to help prevent blockage by rags, paper, etc.
Gathering Method:	Suction lift by vacuum pump.
Sample Lift:	6 feet maximum.
Line Size:	Appears to be 1/4" I.D.
Sample Flow Rate:	Depends upon lift.
Sample Capacity:	A 1 gallon composite sample is accumulated from small aliquots in 8 to 48 hours.
Controls:	A control switch permits the choice of four timing intervals which will cause a 1 gallon sample to be collected in either 8, 16, 24 or 48 hours.
Power Source:	115V ac or 12V dc
Sample Refrigerator:	None
Construction Materials:	Sampling train is all plastic; case is laminated Formica-wood construction.
Basic Dimensions:	12"W x 9"D x 19"H; weighs 19 pounds empty; portable.
Basic Price:	$482 with dry cell battery $583 with N. Cad battery $625 with N. Cad battery and ac power unit.
General Comments:	Unit was designed for flows with a high percentage of suspended solids or where volatiles are present. Sample never passes

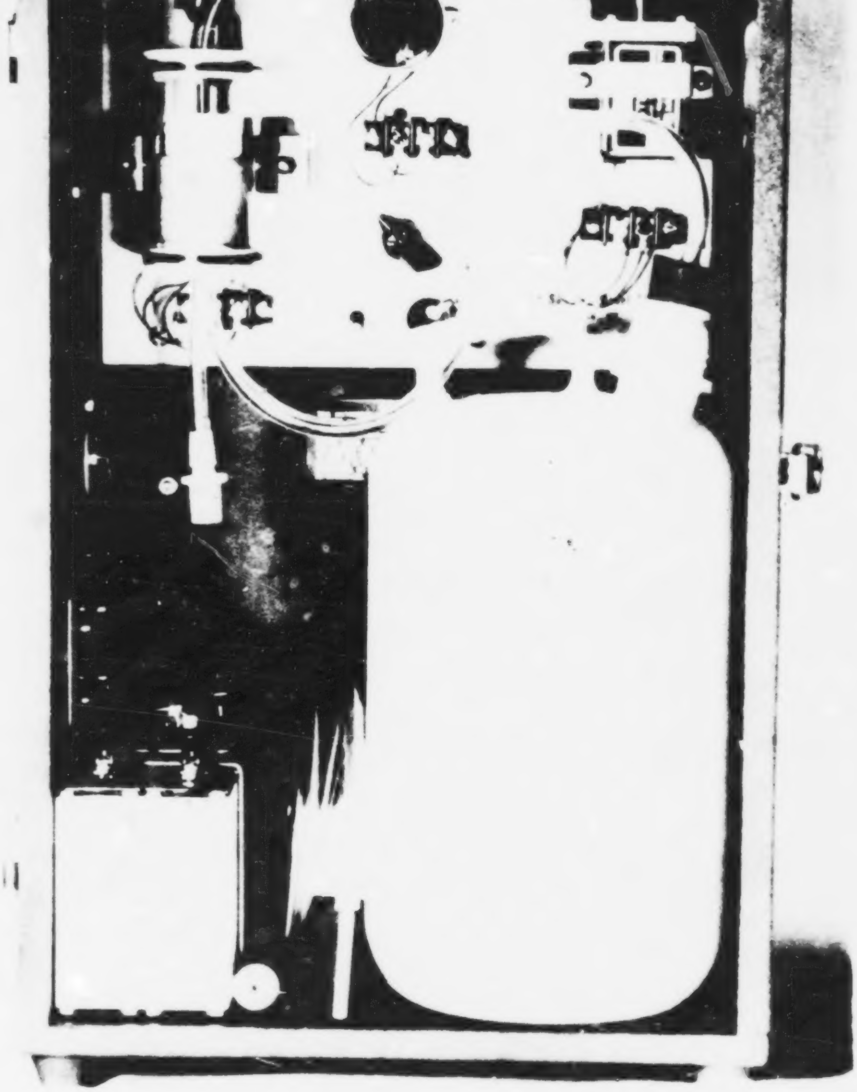

Figure 3. Brailsford Model EV Sampler

Photograph courtesy of Brailsford and Company, Inc.

through pump or valves or orifices which could become clogged. In operation, a small vacuum pump evacuates air from a small metering chamber to which the sample bottle and inlet tube are connected. When chamber is filled to a predetermined level, a magnetic sensing switch stops the pump and opens a vacuum relief valve so a portion of the sample flows into the jug and the remainder backflushes the inlet tube.

Brailsford Model EV Evaluation

1. Specially designed inlet scoop-strainer may help prevent blockage. Rest of sample train should be free from clogging.
2. Minimal obstruction of flow.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocities could affect representativeness of sample at high flow rates.
4. Movement of solids should not hamper operation.
5. No automatic starter - backflushing of inlet tube at end of each cycle provides a self cleaning function of sorts.
6. Unit collects a fixed time interval composite in a 1-gallon jug.
7. Unsuitable for collection of floatables or coarser bottom solids.
8. No refrigerator. Backflushing will help reduce cross contamination.
9. Appears well suited for manhole operation.
10. Unit cannot withstand immersion.
11. Not suitable for operation in freezing ambients.
12. Maximum lift of 6 feet puts restrictions on use of unit.

Designation:	BVS MODEL PP-100
Manufacturer:	Brandywine Valley Sales Company P.O. Box 243 Honey Brook, Pennsylvania 19344 Phone (215) 273-2841
Sampler Intake:	Plastic cylindrical sampling probe which is gravity filled. A row of small holes around the circumference near the bottom forms an inlet screen; weighted base.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Up to 200 feet; requires 1 pound of pressure for every 2 feet of vertical lift.
Line Size:	1/8" I.D.
Sample Flow Rate:	Depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volume is 50 ml; sample composited in 2 1/2-gallon jug in standard model or 1 1/2-gallon jug in refrigerated model.
Controls:	Pressure regulator connecting gas supply is set between 5 and 140 psi (depending upon lift required); sampling interval timer is adjustable to allow from 2 seconds to 60 minutes to elapse between aliquots; manual on/off switch standard. Optional control package accepts signals from external flow meter or totalizer.
Power Source:	One 12-pound can of refrigerant is standard gas source; 12V dc or 117V ac required for refrigerated models or flow proportional control option.
Sample Refrigerator:	Model PPR-100 offers an absorption refrigerator cooled sample case.

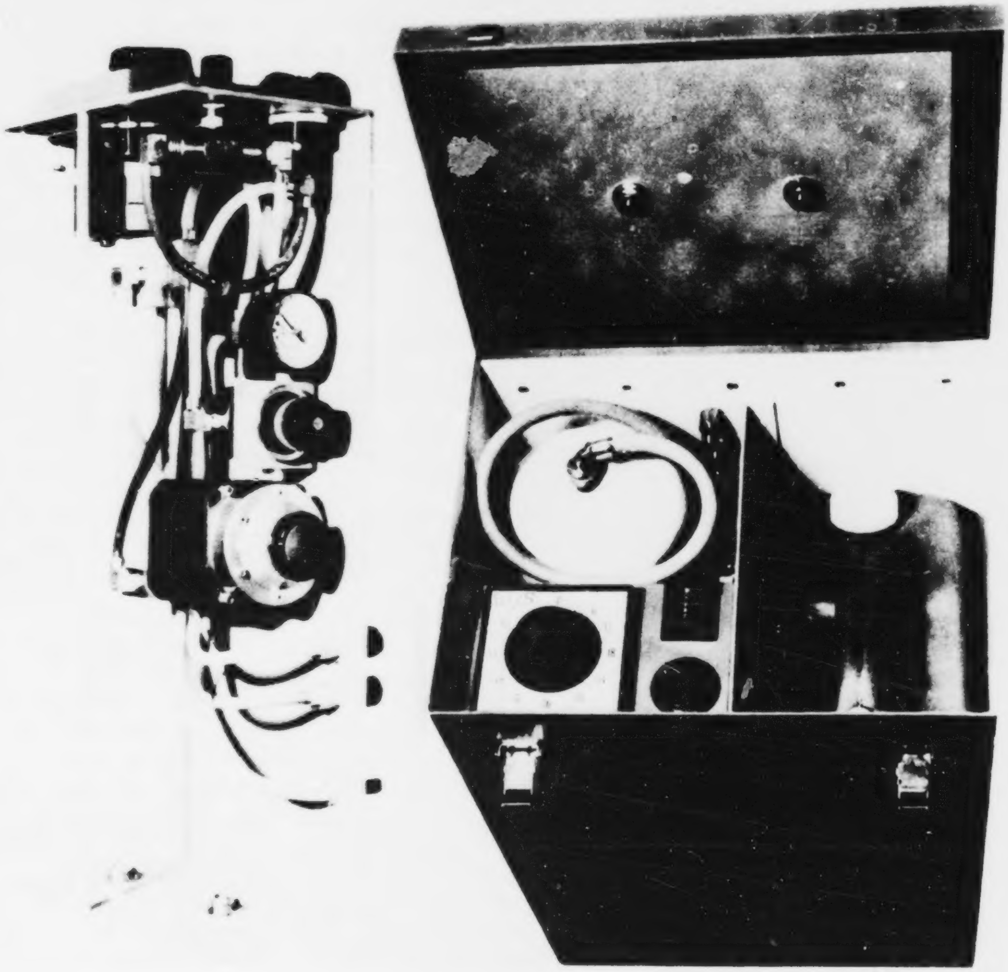

Figure 4. BVS Model PP-100 Sampler

Photograph courtesy of Brandywine Valley Sales Company

Construction Materials: Sampling probe is PVC standard, teflon or stainless steel available; plastic sampling line standard, teflon available; polyethylene sample container; Armorhide finished aluminum case.

Basic Dimensions: Non-refrigerated - 12 1/2"W x 10"D x 18"H. Refrigerated - 17"W x 19 1/2"D x 17 3/4"H. Both models portable.

Base Price: $650 for basic unit including 50 ml sampling probe, one 12 pound disposable cylinder of R-12, and three 20-foot lengths of tubing. Refrigerated model PPR-100 is $850. Add $100 for winterizing system; $250 for solid state control package for flow proportional operation.

General Comments: Timing circuits are controlled by fluidic and pneumatic components. Absorption refrigerator has no moving parts. After each aliquot is gathered, the inlet strainer of the sampling probe is purged by vent pressure from timing valve. Two year parts and labor warranty. Alternate sampling probes available include a surface sampling probe for surface oil, vertical stratum sampling probe for sampling at 6" depth intervals, and float mounted probes for sample quantity accuracy that is independent of head.

BVS Model PP-100 Evaluation

1. Sampling probe is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is unobstructed 1/8" I.D. tube which should pass small solids. No pump to clog.

2. Unless sampling probe is clamped in place, it offers no rigid obstruction to flow.

3. Sampling chamber will fill immediately following intake screen purge at end of previous cycle. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal.

4. Movement of solids in flow could affect position of sampling probe and erode plastic lines if flow is deep enough.

5. No automatic starter. A self cleaning feature for the intake screen is accomplished by using vent pressure from the timing valve to purge it.

6. Collects fixed size aliquots at either preset time intervals or paced by external flow meter if equipped with control option and composits them in a suitable container.

7. Special sampling probe available for surface oil sampling, etc.; appears unsuitable for sampling coarser bottom solids.

8. Automatic refrigerated sample compartment available, but sample size is reduced. Cross contamination appears likely.

9. Unit appears capable of manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Optional winterizing kit is available for use in very cold ambients.

12. Unit has a very wide range of operating head conitions. High lifts will result in faster depletion of gas supply.

Designation:	BVS MODEL SE-400
Manufacturer:	Brandywine Valley Sales Company P.O. Box 243 Honey Brook, Pennsylvania 19344 Phone (215) 273-2841
Sampler Intake	PVC screen over pump inlet.
Gathering Method:	Forced flow from submersible pump.
Sample Lift:	32 feet maximum.
Line Size:	1/2" I.D. inlet hose.
Sample Flow Rate:	1 to 2 gpm typical.
Sample Capacity:	Aliquot volume is a function of the preset diversion time; 2 1/2 gallon composite container is standard, 5 gallon optional.
Controls:	Unit operates on a continuous flow principle, returning uncollected flow to waste. Sample is pumped through a stainless steel, non-clogging diverter valve. Upon receiving a signal from either the built-in timer or an external flow meter, the unit diverts the flow for a preset period of time (adjustable from 0.06 to 1.0 seconds) to the sample container. When operating in the timed sampling mode, the sampling frequency rate is continuously adjustable from 0.2 seconds to 60 hours. When operating in the flow-proportional mode the sampler is triggered directly by the external flow meter.
Power Source:	115V ac
Sample Refrigerator:	Two sizes of automatically refrigerated sample compartments to accomodate either 2 1/2 or 5-gallon containers.

Construction Materials: Sampling train; PVC, stainless steel, plastic, polyethylene, cabinet is aluminum with Armorhide finish.

Basic Dimensions: 24"W x 24"D x 48"H on 8" legs.

Base Price: $2,600 including 2 1/2 gallon size refrigerator, thermostatically controlled heater, 20' of 13/16" O.D. x 1/2" I.D. nylon reinforced plastic inlet tubing, 20' of 1 3/8" O.D. x 1" I.D. nylon reinforced plastic tubing for waste return, clamps, pump support bracket, pump strainer, pump with 36' cord, and flow proportional connection cable. For 5 gallon sized refrigerator add $125; for 30 day strip chart recorder add $260.

General Comments: Submersible pump has magnetic drive, is self-priming. Manufacturer claims design will handle solids to 3/8" diameter.

BVS Model SE-400 Evaluation

1. Large sampling screen over pump inlet can tolerate blockage of a number of ports and still function. Pump and tubing should be free from clogging.

2. Submersible pump and screen present an obstruction to the flow.

3. Should be capable of operation over the full range of flows.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. No automatic starter since designed for continuous flow. Continuous flow serves a self-cleaning function of all except line from diverter to sample bottle.

6. Collects spot samples paced either by built-in timer or external flow meter and composits them in a suitable container.

7. Appears unsuitable for collection of either floatables or coarser bottom solids.

8. Automatic refrigerated sample compartment. Cross contamination should not be too great.

9. Not designed for manhole operation.

10. Cannot withstand total immersion.

11. Can operate in freezing ambients.

12. Upper lift limit of 32 feet does not pose a great restriction on operating head conditions.

Designation: BVS MODEL SE-600

Manufacturer: Brandywine Valley Sales Company
P.O. Box 243
Honey Brook, Pennsylvania 19344
Phone (215) 273-2841

Sampler Intake: Provided by user; sampler has 2" sample inlet connection.

Gathering Method: External head provided by user to give continuous flow through diverter.

Sample Lift: Not applicable.

Line Size: 2" I.D.

Sample Flow Rate: Depends upon installation.

Sample Capacity: Aliquot volume is a function of the preset diversion time; 2 1/2 gallon composite container is standard, 5 gallon optional.

Controls: Unit operates on a continuous flow principle, returning uncollected flow to waste. Sample is pumped through a stainless steel, non-clogging diverter valve. Upon receiving a signal from either the built-in timer or an external flow meter, the unit diverts the flow for a preset period of time (adjustable from 0.06 to 1.0 seconds) to the sample container. When operating in the timed sampling mode, the sampling frequency rate is continuously adjustable from 0.2 seconds to 60 hours. When operating in the flow-proportional mode the sampler is triggered directly by the external flow meter.

Power Source: 115V ac

Sample Refrigerator:	Two sizes of automatically refrigerated sample compartments to accomodate either 2 1/2 or 5-gallon containers.
Construction Materials:	Sampling train; PVC, stainless steel, plastic, polyethylene; cabinet is aluminum with Armorhide finish.
Basic Dimensions:	24"W x 24"D x 48"H on 8" legs.
Base Price:	$2,800 including 2 1/2 gallon size refrigerator, thermostatically controlled heater, and flow proportional connection cable. For 5 gallon sized refrigerator add $125; for 30 day strip chart recorder add $260.
General Comments:	Manufacturer claims design will handle solids to 2" diameter.

BVS Model SE-600 Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should be capable of operation over the full range of flow.
4. Movement of solids should not affect operation.
5. No automatic starter since designed for continuous flow. Continuous flow serves a self-cleaning function of all except line from diverter to sample bottle.
6. Collects spot samples paced either by built-in timer or external flow meter and composits them in a suitable container.
7. Ability to collect floatables or coarser bottom solids will depend upon intake design.
8. Automatic refrigerated sample compartment. Cross contamination should not be too great.

9. Not designed for manhole operation.
10. Cannot withstand total immersion.
11. Can operate in freezing ambients.
12. Operating head provided by user.

Designation: CHICAGO "TRU TEST"

Manufacturer:
Chicago Pump Division
FMC Corporation
622 Diversey Parkway
Chicago, Illinois 60614
Phone (312) 327-1020

Sampler Intake: Provided by user, a screen with maximum openings of 1/2" is recommended; sampler has standard 2" pipe inlet.

Gathering Method: External head to provide flow through a sampling chamber from which a rotating dipper extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.

Sample Lift: Not applicable.

Line Size: Smallest line in sampling train is the one connecting the funnel to the sample bottle; it appears to be about 1 inch.

Sample Flow Rate: Recommended flow rate through sampler is 25 to 50 gpm with 35 gpm as optimum. Minimum velocity in inlet line (2" diameter recommended) should be 2 feet per second. Below 25 gpm fungus growth and settling in sampling chamber will affect the sample quality.

Sample Capacity: Sampling dipper collects a 25 ml sample; a 2 gallon composite container is provided.

Controls: Constant rate sampling (between 3 and 20 samples per hour) is controlled by built-in timer; flow proportional sampling provided by either transmitter control or totalizer control from external flow measuring device.

Power Source: 110V ac

Sample Refrigerator:	Automatic refrigerator to maintain samples at 4° to 10°C is available.
Construction Materials:	Bisphenol polyester resin, polypropylene, stainless steel, and polyethylene; case is laminated fiberglass.
Basic Dimensions:	19 3/8"W x 21"D x 51 3/4"H. Designed for fixed installation.
Base Price:	$2,115 non-refrigerated. $2,578 refrigerated.
General Comments:	Sampling chamber has adjustable weir plates to regulate the sewage level. Manufacturer recommends that intake line be limited to 50 feet or less in length.

Chicago "Tru Test" Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross-contamination.
6. Can collect either flow proportional or fixed time interval composites.
7. Ability to collect samples of floatables and coarser bottom solids will depend upon design of sampling intake.
8. Automatic refrigeration maintains samples at 4° to 10°C. Offers good sample protection and freedom from precontamination; sample composite bottle is sealed to funnel with hose clamps.
9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Does not appear capable of prolonged exposure to extremely cold ambient conditions.

12. Operating head is provided by user.

Designation:	HYDRA-NUMATIC COMPOSITE SAMPLER
Manufacturer:	Hydra-Numatic Sales Company 65 Hudson Street Hackensack, New Jersey 07602 Phone (201) 489-4191
Sampler Intake:	End of suction tube installed to suit by user.
Gathering Method:	Suction lift from centrifugal pump.
Sample Lift:	Up to 15 feet.
Line Size:	1/2" I.D.
Sample Flow Rate:	1.5 gpm.
Sample Capacity:	Aliquot size is adjusted (based upon anticipated flow rates where external flow meter is to be employed) to fill the 5 gallon composite container in 24 hours.
Controls:	Sampler receives signals from external flow meter through a primary relay and clock system, the clock serving as a memory-collecting impulses representing a given flow - at which time a known, pre-set volume of sample is drawn. The volume of sample is controlled by a finely calibrated clock which opens a free-port solenoid valve for a preset time period thereby diverting the flow to the sample container. A built-in timer can be used to pace the sampler when no flow meter is available. It can either be programmed if rough estimates of daily flow variations are known or function as a fixed time interval pacer.
Power Source:	115V ac
Sample Refrigerator:	None

Construction Materials: Polyethylene sample container, Tygon sampling lines with bronze fittings and connections, bronze valves and pump, stainless steel available as alternate; cabinet is stainless steel.

Basic Dimensions: 36"W x 13 1/8"D x 36"H; portable.

Base Price: $1800.

Hydra-Numatic Composite Sampler Evaluation

1. Fairly large line size and "non-clog" pump should give freedom from clogging; manufacturer recommends unit for streams with high solids content.
2. Obstruction of flow will depend upon way user mounts intake tube.
3. Should operate reasonably well over all flow conditions.
4. Solids in the fluid flow should not impede operation.
5. No automatic starter. Continuous flow serves a self-cleaning function.
6. Unit collects aliquots paced by external flow meter or built-in timer and composits them in a suitable container.
7. Collection of samples of floatables and bottom solids would require specially designed intake by user.
8. No refrigeration available; sample would appear to be reasonably well protected from damage.
9. Unit appears capable of operation in a high humidity environment, but is too large to pass down a standard manhole.
10. Unit cannot withstand total immersion.
11. Unit appears able to tolerate freezing ambients, at least for moderate periods of time.
12. Lift limit of 15 feet poses some restrictions on use of unit.

Designation:	INFILCO AUTOMATIC
Manufacturer:	Westinghouse Electric Corporation Infilco Division Box 2118 Richmond, Virginia 23216 Phone (703) 643-8481
Sampler Intake:	Provided by user; sampler has standard 2" pipe inlet.
Gathering Method:	External head to provide flow through a sampling chamber from which an oscillating dipper extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.
Sample Lift:	Not applicable.
Line Size:	Smallest line in sampling train is the one connecting the funnel to the bottle; it appears to be about 1 inch.
Sample Flow Rate:	Recommended flow rate through sampler is 10 to 20 gpm.
Sample Capacity:	Sampling dipper collects a 10 or 20 ml sample; a 1 gallon composite container is provided.
Controls:	Constant rate sampling (between 1 and 15 samples per hour) is controlled by built-in timer; flow proportional sampling provided by signal from external flow measuring device.
Power Source:	115V ac
Sample Refrigerator:	Automatic refrigerator to maintain samples at 4° to 10°C is available.
Construction Materials:	Case is pressed steel.
Basic Dimensions:	About 2'W x 2'D x 5'H. Designed for fixed installation.

Base Price: $4180; add $220 for refrigeration and flow proportioning capability.

General Comments: Sampling chamber has adjustable weir plates to regulate the sewage level.

Infilco Automatic Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross-contamination.
6. Can collect either flow proportional or fixed time interval composites. Representativeness of sample will be a function of sample intake which is not a part of this unit.
7. Collection of samples of floatables and coarser bottom solids will depend upon design of sampling intake.
8. Automatic refrigeration maintains samples at 4° to 10°C. Offers good sample protection and freedom from precontamination.
9. Not designed for confined space or manhole operation.
10. Cannot withstand total immersion.
11. Does not appear capable of prolonged exposure to extremely cold ambient conditions.
12. Operating head is provided by user.

Designation:	ISCO MODEL 1391
Manufacturer:	Instrumentation Specialties Co., Inc. P.O. Box 5347 Lincoln, Nebraska 68524 Phone (402) 799-2441
Sampler Intake:	End of 22 foot suction tube installed to suit by user. When provided with operational multiplexer and source selection valve, up to four suction tubes can be used for sampling from four different locations.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	26 foot maximum lift; 96 percent delivery at 8 feet, 80 percent at 18 feet.
Line Size:	1/4" I.D.
Sample Flow Rate:	Greater than 167 ml per minute depending upon lift.
Sample Capacity:	Sample size can be switch selected from 70 ml to 490 ml at 3 foot lift. Twenty-eight 500 ml sample bottles are provided and are used for collecting descrete samples or four-sample composites when used with the optional multiplexer.
Controls:	The time interval between collections can be varied in 1/2 hour increments from 1/2 to 6 hours; an optional timer can be varied in 1/4 hour increments from 1/4 to 3 hours - both use a clock mechanism. Connections for an external flow meter to collect samples on the basis of stream flow rate are provided.
Power Source:	118V ac or 12V dc

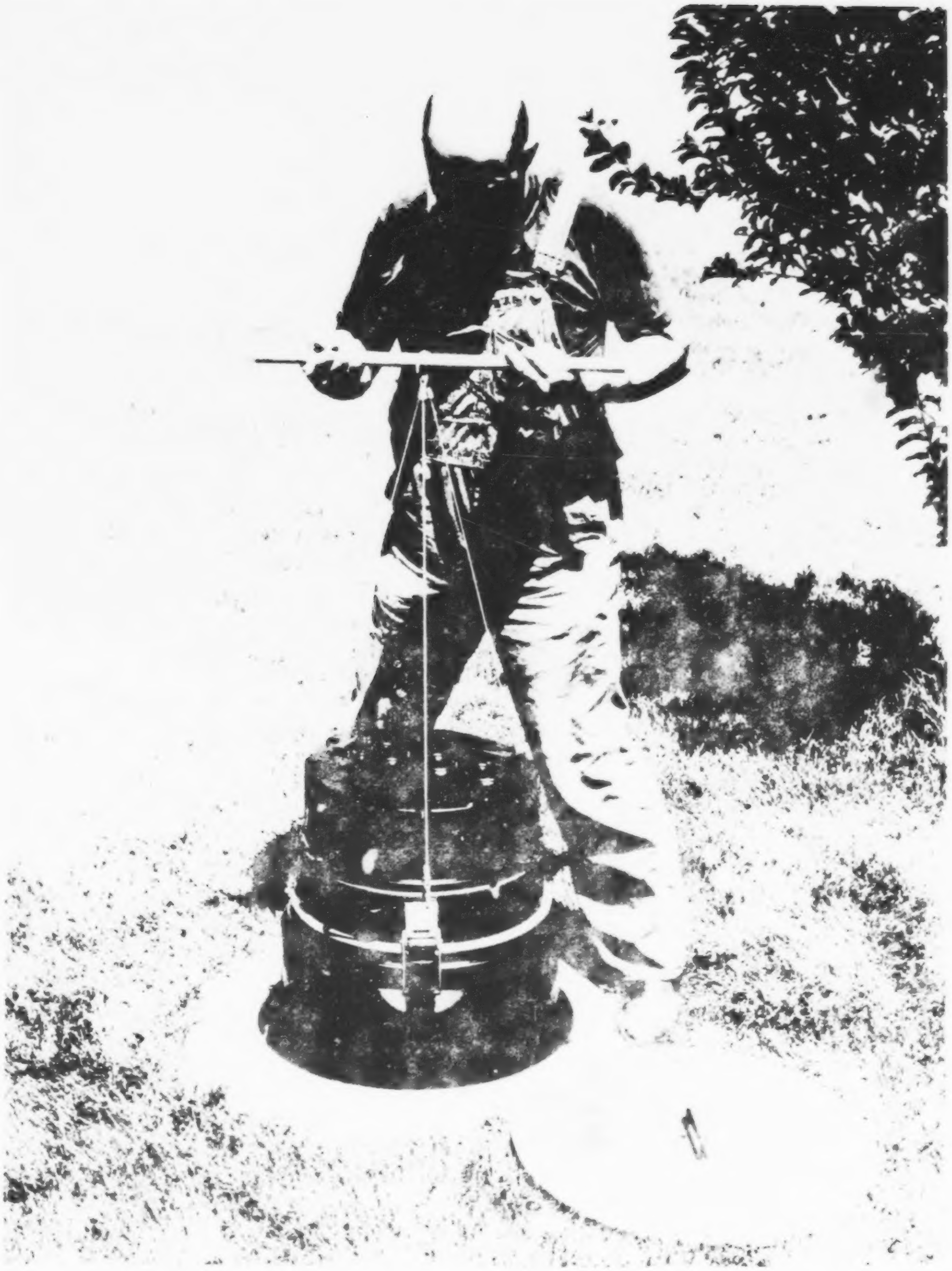

Figure 5. ISCO Model 1391 Sampler

Photograph courtesy of Instrumentation Specialities Co., Inc.

Sample Refrigerator: Has ice cavity for cooling; will maintain samples up to 40°F below ambient for at least 24 hours.

Construction Materials: All plastic construction including insulated case, tubing, and sample bottles; stainless steel hardware.

Basic Dimensions: 19 1/2" diameter x 21"H; weighs 40 pounds; portable.

Base Price: $995; add $95 for N. Cad batteries, $100 for multiplexer.

General Comments: Sampler will withstand accidental submersion for short periods of time. All electrical and mechanical components are waterproofed; the programming unit is sealed in a vapor-tight housing that contains a regeneratable dessicant. Manufacturer claims peristaltic pump tubing can fill more than 80,000 sample bottles before requiring replacement. At least 100 500-ml samples may be taken on a single 14-hour battery charge. A rotating "clog-proof" funnel delivers samples to the distributer plate which channels them to their individual bottles. After each sample the pump automatically reverses itself to purge intake tube and minimize cross-contamination.

ISCO Model 1391 Evaluation

1. Plugging or clogging will depend upon user installation of intake line; the unobstructed 1/4" inside diameter sampling line, peristaltic pump, and "non-clog" funnel should pass small solids without difficulty.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocities could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter. Backflushing after taking each sample provides a self cleaning function of sorts.

6. Unit with optional multiplexer and source selection valve can sample from up to four individual locations and composite in a single bottle. Can be paced by either built-in timer or external flow meter and collect 28 samples of up to 500 ml capacity each.

7. Unit does not appear suitable for collection of coarser bottom solids; collection of floatables will depend on user mounting of a suitable intake.

8. Unit affords good sample protection; insulated case has ice cavity which will keep samples up to 40°F below ambient for over 24 hours.

9. Unit comes with a harness for suspending it in manholes.

10. Unit can withstand total immersion for short periods of time.

11. Unit would not appear to function well after prolonged exposure to freezing ambients.

12. Unit should be able to sample over a wide range of operating head conditions.

Designation:	LAKESIDE TREBLER MODEL T-2
Manufacturer:	Lakeside Equipment Corporation 1022 East Devon Avenue Bartlett, Illinois 60103 Phone (312) 837-5640
Sampler Intake:	Specially designed scoop.
Gathering Method:	Mechanical; rotating scoop traverses entire depth of flow; as scoop is rotated out of flow the sample drains by gravity through the hub and into a composite sample jar.
Sample Lift:	Unit must be in flow stream.
Line Size:	1/2" I.D.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Scoop is shaped to gather a volume of sample that is proportional to the channel flow; can vary typically from 300 to 600 ml when installed in a Parshall flume.
Controls:	Timer can be used to trigger sampling cycle at any desired interval of a 1 hour period.
Power Source:	115V ac
Sample Refrigerator:	Automatic refrigerator available which maintains sample temperature at approximately 4°C.
Construction Materials:	Cast aluminum frame, steel sprockets and chain drive, plexiglass or cast aluminum scoop, plastic pipe, polyethylene sample bottle.
Basic Dimensions:	Approximately 2 to 3 feet of head room above flume is required. Other dimensions depend upon size of flume. Refrigerator case is 30"W x 24"D x 36"H.

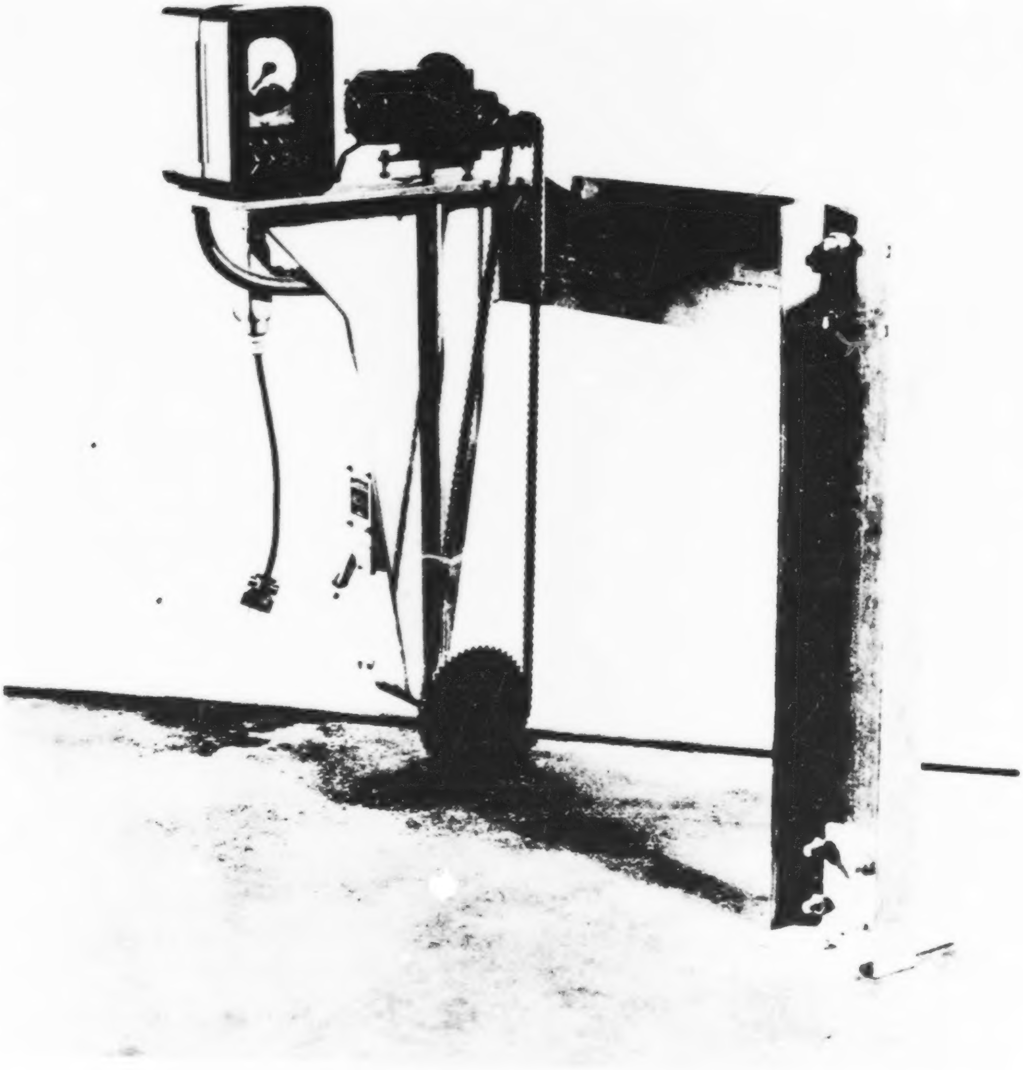

Figure 6. Lakeside Trebler Model T-2 Sampler

Photograph courtesy of Lakeside Equipment Corp.

Base Price:
$688 with plexiglass scoop.
$962 with timer.
Add $615 for refrigerator.

General Comments:
Without timer the unit takes 30 samples per hour. For accurate sampling the unit must operate in conjunction with a Parshall flume or weir. For raw sewage or industrial wastes with high settleable solids count a Parshall flume is recommended. Daily inspection and weekly cleaning is recommended.

Lakeside Trebler Model T-2 Evaluation

1. Scoop is not likely to pick up any solids large enough to clog sample line.
2. Scoop presents an obstruction over the entire depth of flow during sampling cycle.
3. Scoop must be designed for range of flows anticipated in conjunction with flume. This range has certain limitations.
4. Movement of solids could interfere with scoop rotation; abrasive wear on plexiglass scoop could be high.
5. No automatic starter; no self cleaning features.
6. Collects a sample for compositing from throughout the entire depth of flow that is proportional to depth and hence flow rate through the flume.
7. Will afford some capability of sampling floatables as well as bottom solids.
8. Standard unit has no sample container. Optional refrigerator would appear to offer reasonable protection.
9. Designed for operation in the flow stream but requires a Parshall flume for best operation which would rule out most manholes.
10. Unit cannot withstand total immersion.

11. Unit is not designed to operate in freezing ambients.

12. Unit must be in flow stream to function.

Designation:	MARKLAND MODEL 1301
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada Telephone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Depends upon pressure available.
Line Size:	1/4" I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composits 75 ml aliquots into a 2-gallon bottle.
Controls:	Solid state clock allows selecting intervals between aliquots of 15-60 minutes. Optional controller allows pacing from external flow meter.
Power Source:	Compressed air bottle plus two 60-volt dry cell lantern batteries.
Sample Refrigerator:	None
Construction Materials:	Standard intake housing is aluminum alloy, stainless steel or PVC available as alternates; standard "duckbill" is EPT, Buna-N or Viton available; Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle, fiberglass case.
Basic Dimensions:	Sample intake is 2 7/8" diameter by 5" high; case is 17"W x 12"D x 28"H; weighs 60 pounds; portable.

Base Price: $995; add $115 for stainless steel or PVC intake, $20 for Viton "duckbill", $100 for flow proportional adapter; all prices include air freight and duty.

General Comments: The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom (about 1 1/2" diameter) and flattens out to a flaired top (about 3" high) where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the vertical inlet and through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity.

Markland Model 1301 Evaluation

1. Sampler intake should be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure (15-35 psi) will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

5. Has no automatic start or self-cleaning features.

6. Collects spot samples at either preset time intervals or paced by an external flowmeter and composits them in a suitable container.
7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.
8. No refrigeration is provided. Cross-contamination appears likely.
9. Unit is designed for manhole operation.
10. Cannot withstand total immersion.
11. Should be able to operate in freezing ambients for some period of time.
12. With a fully charged gas bottle lifts in excess of 30 feet should be obtainable putting very little restriction on operating head conditions.

Designation:	MARKLAND MODEL 101
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Telephone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Depends upon pressure available.
Line Size:	1/4" I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composits 75 ml aliquots into a 2-gallon bottle.
Controls:	A cycle timer with field adjustable cams allows taking an aliquot every 10, 15, 20, 30, or 60 minutes.
Power Source:	Plant air for Model 101; Model 2101 includes air compressor and motor; 110V ac.
Sample Refrigerator:	6 cubic feet automatic refrigerator to hold either a 2- or 5-gallon bottle available.
Construction Materials:	Standard intake housing is aluminum alloy, stainless steel or PVC available as alternates; standard "duckbill" is EPT, Buna-N or Viton available; Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle.
Basic Dimensions:	Sample intake is 2 7/8" diameter by 5" high; wall mounted control box is 6"W x 4"D x 6"H; fixed installation.

Base Price: $540 for Model 101 including control box, remote sampling intake, air filter, regulator and pressure gauge, 100 feet of tubing, and 2 gallon sample collection bottle; $580 for Model 2101 including control box, remote sampling intake, air compressor and motor, 100 feet of tubing, and 2 gallon sample collection bottle; add $115 for stainless steel or PVC intake, $20 for Viton "duckbill", $325 for refrigerator, $10 for 5 gallon sample container; all prices include air freight and duty.

General Comments: The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom (about 1 1/2" diameter) and flattens out to a flaired top (about 3" high) where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity.

Markland Model 101 Evaluation

1. Sampler intake should be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure (15-30 psi) will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

5. Has no automatic start or self-cleaning features.

6. Collects spot samples at preset time intervals and composits them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigeration is available as an option. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. Lifts in excess of 30 feet should be obtainable putting very little restriction on operating head conditions.

Designation:	MARKLAND MODEL 102
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Telephone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Depends upon pressure available.
Line Size:	1/4" I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composits 75 ml aliquots into a 2-gallon bottle.
Controls:	A cycle timer with field adjustable cams allows taking an aliquot every 10, 15, 20, 30, or 60 minutes.
Power Source:	Plant air plus 110V ac.
Sample Refrigerator:	6 cubic foot automatic refrigerator to hold either a 2- or 5-gallon bottle available.
Construction Materials:	Standard intake housing is aluminum alloy, stainless steel or PVC available as alternates; standard "duckbill" is EPT, Buna-N or Viton available; Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle, fiberglass case.
Basic Dimensions:	Sample intake is 2 7/8" diameter by 5" high; wall mounted control box is 10"W x 5"D x 12"H; fixed installation.

Base Price: $825 including control box, remote sampling intake, air filter, regulator and pressure gauge, 100 feet of tubing, and 2 gallon sample collection bottle; add $115 for stainless steel or PVC intake, $20 for Viton "duckbill", $325 for refrigerator, $10 for 5 gallon sample container; all prices include air freight and duty.

General Comments: The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom (about 1 1/2" diameter) and flattens out to a flaired top (about 3" high) where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the vertical inlet and through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity. The control box has a pinch valve on the sample line which squeezes it closed and keeps the sample intake housing filled with pressurized air between aliquot ejections. This feature is useful when sampling liquids with high solids content which would tend to settle out in the intake while waiting to be ejected. Also, the air pressurization provides a reverse air purge back through the "duckbill" thereby prividing a sort of self cleaning action should any solids build up in the "duckbill" inlet. The manufacturer recommends this model in

particular for raw sewage or
liquids with solids content over
200 PPM.

Markland Model 102 Evaluation

1. Sampler intake sould be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure (15-35 psi) will also help prevent clogging.
2. Sampler intake presents a rigid obstruction to the flow.
3. Representativeness of sample is questionable at high flow rates.
4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.
5. Has no automatic starter. Reverse air purge through "duckbill" provides a sort of self-cleaning action.
6. Collects spot samples at preset time intervals and composits them in a suitable container.
7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.
8. Automatic refrigeration is available as an option. Cross-contamination appears likely.
9. Unit is not designed for manhole operation.
10. Cannot withstand total immersion.
11. Should be able to operate in freezing ambients for some period of time.
12. Lifts in excess of 30 feet should be obtainable putting very little restriction on operating head conditions.

Designation:	MARKLAND MODEL 104T
Manufacturer:	Markland Specialty Engineering Ltd. Box 145 Etobicoke, Ontario (Canada) Telephone (416) 625-0930
Sampler Intake:	Small gravity filled sample chamber equipped with patented non-clogging "duckbill" inlet control.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Depends upon pressure available.
Line Size:	1/4" I.D.
Sample Flow Rate:	Varies with pressure and lift.
Sample Capacity:	Composits 75 ml aliquots into a 2-gallon bottle.
Controls:	Solid state predetermining digital counter accepts signals from an external flowmeter to gather samples proportional to flow. Optional solid state clock allows sampling at predetermined time intervals.
Power Source:	Plant air for Model 104T; Model 2104T includes air compressor and motor; 110V ac.
Sample Refrigerator:	6 cubic foot automatic refrigerator to hold either a 2- or 5-gallon bottle available.
Construction Materials:	Standard intake housing is aluminum alloy, stainless steel or PVC available as alternates; standard "duckbill" is EPT, Buna-N or Viton available; Tygon tubing, stainless steel or plastic fittings, polyethylene sample bottle, fiberglass case.
Basic Dimensions:	Sample intake is 2 7/8" diameter by 5" high; fixed installation.

Base Price: $975 for Model 104T including control box, remote sampling intake, air filter, regulator and pressure gauge, 100 feet of tubing, and 2 gallon sample collection bottle; $1,005 for Model 2104T including control box, remote sampling intake, air compressor and motor, 100 feet of tubing, and 2 gallon sample collection bottle; add $115 for stainless steel or PVC intake, $20 for Viton "duckbill", $325 for refrigerator, $10 for 5 gallon sample container, $195 for plug-in solid state clock module; all prices include air freight and duty.

General Comments: The heart of the sampler is the patented rubber "duckbill" in the sample intake housing. It is round on the bottom (about 1 1/2" diameter) and flattens out to a flaired top (about 3" high) where the opening is simply a slit. When the intake is vented to atmosphere, the hydrostatic liquid head forces a sample up through the vertical inlet and through the "duckbill" slit, which acts like a screen (the lips can only open a limited amount), until the pressure is equalized. When air pressure is applied to raise the sample the "duckbill" lips close (acting as a check valve), and the squeezing-shut progresses downwards toward the bottom inlet expelling ahead (in a sort of milking action) any contained solids which fall back into the stream due to gravity. The two digit counter, when connected to an external flowmeter providing dry contact pulsing closed momentarily with frequency proportional to flow, counts down from the preset point to zero. When zero is reached, the sampling circuit latches in and extracts an aliquot while simultaneously resetting the counter back to the reset point. Pulses received while the aliquot is being ejected are counted without loss.

Markland Model 104T Evaluation

1. Sampler intake should be free from clogging; "duckbill" will not pass any solids large enough to clog sample line; relatively high discharge pressure (15-35 psi) will also help prevent clogging.

2. Sampler intake presents a rigid obstruction to the flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of large objects in the flow could damage or even physically destroy the sampler intake.

5. Has no automatic start or self-cleaning features.

6. Collects spot samples at either preset time intervals with clock option or paced by an external flowmeter and composits them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigeration is available as an option. Cross-contamination appears likely.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Should be able to operate in freezing ambients for some period of time.

12. Lifts in excess of 30 feet should be obtainable putting very little restriction on operating head conditions.

Designation:	N-CON SURVEYOR MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	End of 1/2 inch sampling tube installed to suit by user.
Gathering Method:	Suction lift by self-priming centrifugal pump.
Sample Lift:	6 feet maximum.
Line Size:	1/4" I.D. line connects diverter to sample container.
Sample Flow Rate:	5 gpm.
Sample Capacity:	Aliquot size adjustable from approximately 150 ml to 5000 ml; composited in user supplied container (2 1/2-gallon jug to 55-gallon drum).
Controls:	Timer may be set to collect from 2 to 30 samples per hour; may also be paced by signals from external flow meter.
Power Source:	115V ac or 12V dc for timer operation only (user supplies batteries).
Sample Refrigerator:	None
Construction Materials:	Sampling train is PVC, nylon, epoxy resin, and Buna-N.
Basic Dimensions:	Very small portable unit. User provided sample container will be largest component.
Base Price:	$275.
General Comments:	When sample is to be collected, the self-priming pump operates for a preset period of time which determines the volume of the sample.

Approximately 15 percent of the pump's throughput is diverted to the sample receiver by a fluidic diverter. When the pump stops the fall of liquid level in the exhaust line backwashes to help prevent clogging.

N-Con Surveyor Model Evaluation

1. Unit would not appear to be vulnerable to clogging.
2. Will depend upon way user mounts end of sampling tube.
3. Should operate reasonably well under all flow conditions.
4. Movement of solids should not hamper operation.
5. No automatic starter. Fall of liquid in exhaust line when pump stops will backwash giving a sort of self cleaning action.
6. Can collect either timer or flow meter paced samples and composite them in a suitable container. Representativeness of sample will depend upon user mounting of intake tube.
7. Unsuitable for collection of samples of floatables and coarser bottom solids without specially designed intake by user.
8. No refrigeration, no sample protection. Small amount of cross contamination might be experienced.
9. Should be able to operate in manhole enviroment.
10. Cannot withstand immersion.
11. Not ideally suited for operation in freezing ambients.
12. Maximum lift of 6 feet limits location of unit.

Designation:	N-CON SCOUT MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Plastic strainer approximately 2" diameter x 8" long and perforated with 1/8" holes.
Gathering Method:	Suction lift by peristaltic pump.
Sample Lift:	Up to 15 feet.
Line Size:	1/4" I.D.
Sample Flow Rate:	150 ml per minute.
Sample Capacity:	Aliquot size is adjustable via a solid state timer to suit hydraulics of installation and sampling programs; composited in a 1-gallon container.
Controls:	24-hour key wound clock turns programmer drum which can be set to collect 1 to 8 samples per hour.
Power Source:	12V dc dry cell battery.
Sample Refrigerator:	None
Construction Materials:	Sampling train PVC, silicon rubber, polyethylene; case is compression molded fiberglass.
Basic Dimensions:	14"W x 6"D x 17"H; weighs 22 pounds empty.
Base Price:	$450.
General Comments:	On signal, pump starts and runs in reverse to clear pump and tubing of previous sample, then runs forward to deliver sample to container. Case is weatherproof.

N-Con Scout Model Evaluation

1. Peristaltic action of pump should reduce probability of clogging.

2. Obstruction of flow will depend upon way user mounts intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. At start of each cycle pump operates in reverse to clear line of previous sample to help minimize cross contamination and offer a sort of self cleaning.

6. Unit collects samples at preset time intervals and composits them in container. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collecting floatables or coarser bottom solids.

8. No refrigeration. Reasonably good sample protection (container is connected only to pump). Cross contamination should be small.

9. Designed to operate in manhole environment.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing ambients.

12. Maximum lift of 15 feet places some restriction on use of unit.

Designation:	N-CON SENTRY MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Plastic strainer approximately 2" diameter x 8" long and perforated with 1/8" holes.
Gathering Method:	Suction lift by peristaltic pump.
Sample Lift:	Up to 15 feet.
Line Size:	1/4" I.D.
Sample Flow Rate:	150 ml per minute.
Sample Capacity:	Collects 24 discrete 250 ml samples made up of from 2 to 8 individual aliquots over a period of 3, 6, 8, 12, or 24 hours.
Controls:	Same as Scout Model.
Power Source:	12V dc dry cell battery standard, optional 115V ac converter.
Sample Refrigerator:	None
Construction Materials:	Same as Scout, but glass sample jars.
Basic Dimensions:	16"W x 14"D x 13"H; weighs 35 pounds empty.
Base Price:	$895.
General Comments:	Similar in operation to the Scout Model except for capability to collect discrete samples. Sampler automatically shuts off after 24th bottle is filled.

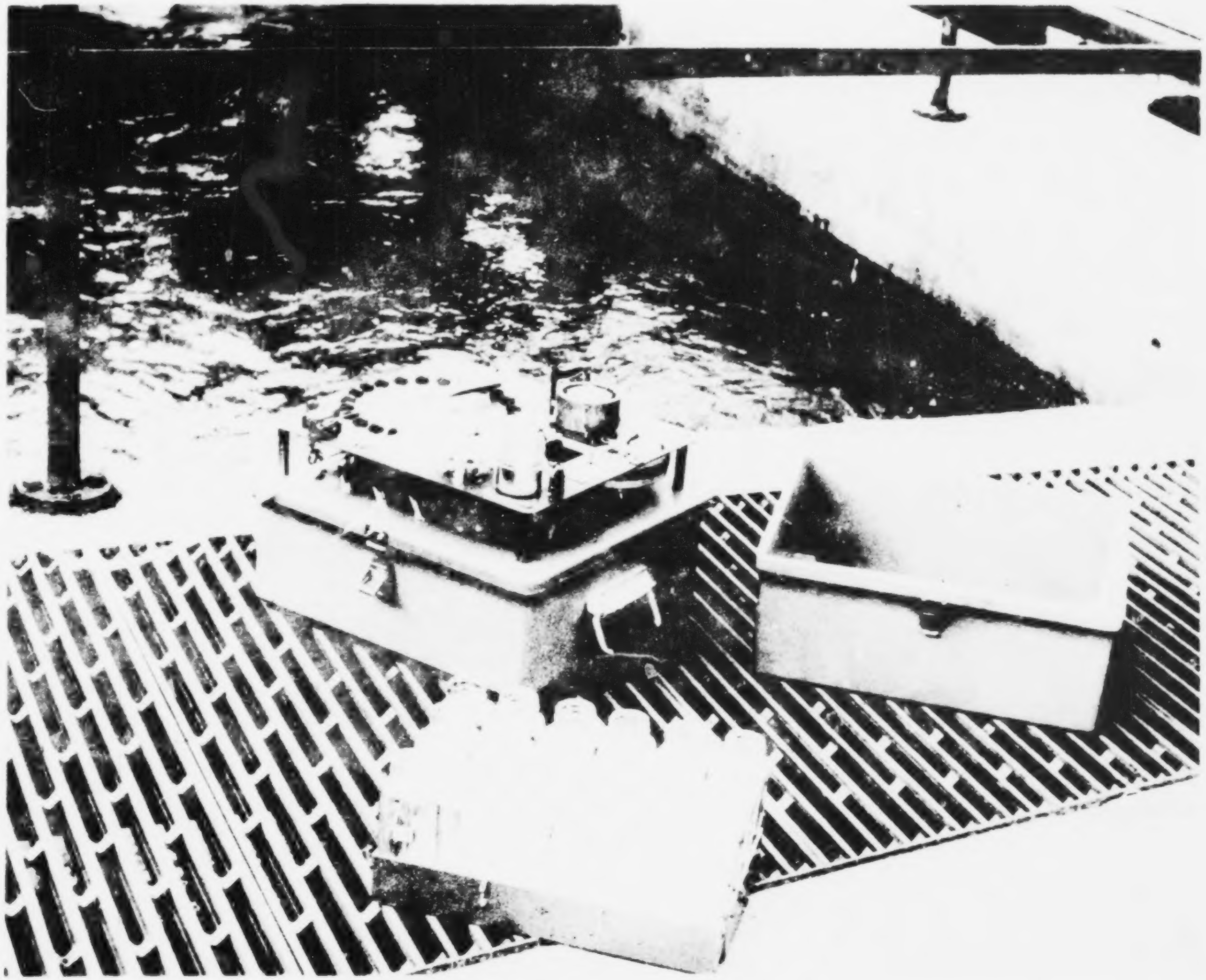

Figure 7. N-Con Sentry Model Sampler

Photograph courtesy of N-Con Systems Co., Inc.

N-Con Sentry Model Evaluation

1. Peristaltic action of pump should reduce probability of clogging.

2. Obstruction of flow will depend upon way user mounts intake.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids should not hamper operation.

5. No automatic starter. At start of each cycle pump operates in reverse to clear line of previous sample to help minimize cross contamination and offer a sort of self cleaning.

6. Unit collects 24 discrete samples made up of 2 to 8 individual aliquots at preset time intervals. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. No refrigeration. Reasonably good sample protection. Cross contamination should be small.

9. Designed to operate in manhole environment.

10. Cannot withstand total immersion.

11. Not suited for operation in freezing ambients.

12. Maximum lift of 15 feet places some restriction on use of unit.

Designation: N-CON TREBLER MODEL

Manufacturer: N-Con Systems Company, Inc.
308 Main Street
New Rochelle, New York 10801
Phone (914) 235-1020

Sampler Intake: Specially designed scoop.

Gathering Method: Mechanical; oscillating scoop is lowered into the channel traversing entire depth of flow, then returned to its raised position, draining the collected sample by gravity through a swivel fitting coaxial with the hub into a sample container.

Sample Lift: Unit must be in flow stream.

Line Size: 1/2" I.D. pipe connects hub to sample container.

Sample Flow Rate: Not applicable.

Sample Capacity: Scoop is shaped to gather a volume of liquid that is proportional to the channel flow; can vary typically from 200 to 600 ml when installed in a Parshall flume.

Controls: Electric timer may be set to take from 3 to 20 samples per hour.

Power Source: 115V ac

Sample Refrigerator: Automatic refrigerator available which provides 4° to 10°C sample storage.

Construction Materials: Cast aluminum frame and cover; PVC scoop, plastic pipe.

Basic Dimensions: Approximately 2 to 3 feet of headroom is required. Other dimensions depend upon size of flume or weir. Refrigerator case is 24"W x 26"D x 30"H.

Base Price: $995; add $565 for refrigerator.

General Comments: Drive mechanism and control programmer are totally enclosed and weatherproof, with no exposed chains or sprockets. Oscillating action of scoop permits installation in smaller weir boxes and manholes and lessens the chances of fouling with rags, etc., or being damaged by floating debris. Must operate in conjunction with a weir or Parshall flume.

N-Con Trebler Model Evaluation

1. Scoop is not likely to pick up any solids large enough to clog sample line.
2. Scoop presents an obstruction over the entire depth of flow during sampling cycle.
3. Scoop must be designed for range of flows anticipated in conjunction with flume. This range has certain limitations.
4. Movement of solids could interfere with scoop rotation; abrasive wear on rigid, high impact PVC scoop should not be too great.
5. No automatic starter; no self cleaning features.
6. Collects a sample for compositing from throughout the entire depth of flow that is proportional to depth and hence flow rate through the flume.
7. Will afford some capability of sampling floatables as well as bottom solids.
8. Standard unit has no sample container. Optional refrigerator would appear to offer reasonable protection.
9. Designed for operation in the flow stream, but requires a Parshall flume for best operation which would rule out most manholes.
10. Unit cannot withstand total immersion.
11. Unit is not designed to operate in freezing ambients.
12. Unit must be in flow stream to function.

Designation:	N-CON SENTINEL MODEL
Manufacturer:	N-Con Systems Company, Inc. 308 Main Street New Rochelle, New York 10801 Phone (914) 235-1020
Sampler Intake:	Provided by user; sampler has standard 2" pipe inlet.
Gathering Method:	External head to provide flow through a sampling chamber from which an oscillating dipper (after McGuire and Stormguard) extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.
Sample Lift:	Not applicable.
Line Size:	Smallest line in sampling train is the one connecting the funnel to the sample bottle; it appears to be about 1 inch.
Sample Flow Rate:	10 to 50 gpm.
Sample Capacity:	Sampling dipper collects a 25 ml sample; a 2 gallon composite container is provided.
Controls:	Constant rate sampling (between 3 and 20 samples per hour) is controlled by built-in timer; flow proportional composits are collected by connecting to the electrical output of a pulse duration or integrating external flow meter.
Power Source:	115V ac
Sample Refrigerator:	Automatic refrigerator to maintain sample at 4° to 10°C is available.
Construction Materials:	PVC and polyethylene.
Basic Dimensions:	22"W x 28"D x 58"H. Designed for fixed installation. Weighs 185 pounds.

Base Price: $2,350 with refrigerator.

General Comments: Manufacturer claims representative samples assured due to design of sample chamber which causes thorough mixing of liquid before it flows over adjustable weir.

N-Con Sentinel Model Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross contamination.
6. Can collect either flow proportional or fixed time interval composites. Representativeness of sample will be a function of sample intake which is not a part of this unit.
7. Collection of floatables and coarser bottom solids will depend upon design of sampling intake.
8. Automatic refrigeration maintains samples at 44° to 10°C. Offers good sample protection and freedom from precontamination.
9. Not designed for confined space or manhole operation.
10. Cannot withstand total immersion.
11. Does not appear capable of prolonged exposure to extremely cold ambient conditions.
12. Operating head is provided by user.

Designation:	PHIPPS AND BIRD DIPPER-TYPE
Manufacturer:	Phipps and Bird, Inc. 303 South 6th Street Richmond, Virginia 23205 Phone (703) 644-5401
Sampler Intake:	Dipping bucket.
Gathering Method:	Mechanical; dipper on sprocket-chain drive.
Sample Lift:	Up to 10 feet standard, longer on special order.
Line Size:	Not applicable.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Dipping bucket holds 200 ml; user supplies sample composite container to suit.
Controls:	Sampling cycle can either be started at fixed, selected intervals from a built-in timer (15 minutes) or in response to signals from an external integrating flow meter.
Power Source:	115V ac or 12V dc
Sample Refrigerator:	None
Construction Materials:	Dipper and funnel are stainless steel; sprockets and chain are steel (stainless available), supports are angle iron.
Basic Dimensions:	Base is 16" x 24" and will pass through a 30" diameter opening, unit extends 3' above base. Fixed installation.
Base Price:	$725; $1,145 in stainless steel; $1,980 for explosion proof version; $2,450 for explosion proof version in stainless steel.

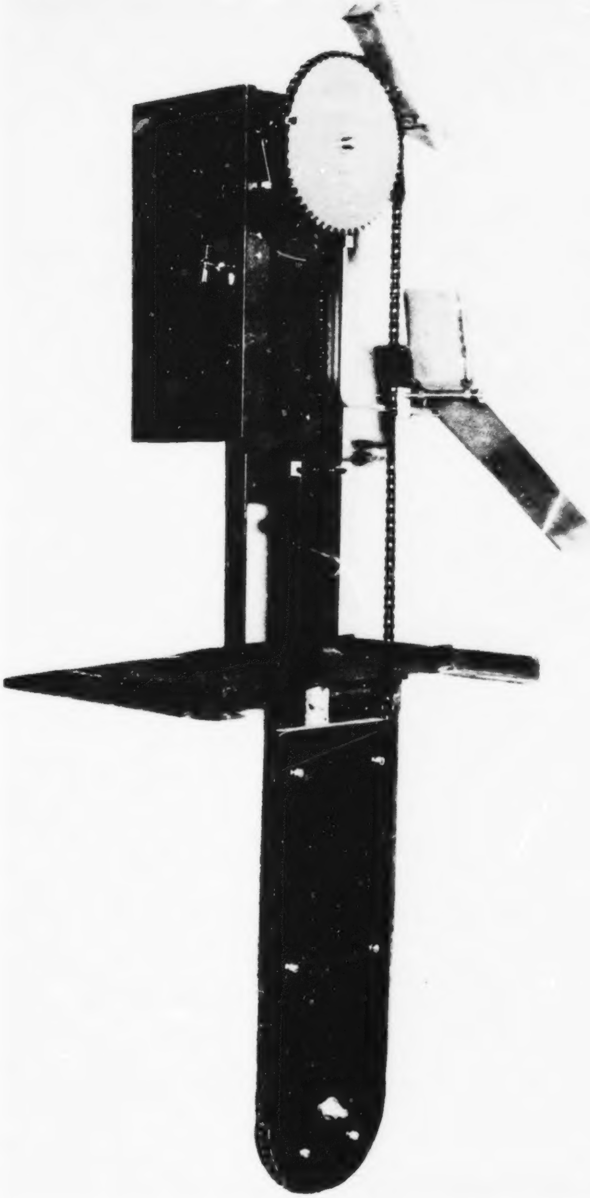

Figure 8. Phipps and Bird Dipper-Type Sampler

Photograph courtesy of Phipps and Bird, Inc.

General Comments: Manufacturer states unit was designed to sample trash laden streams where it is not possible to operate a pump. A circuit breaker prevents damage if unit becomes jammed.

Phipps and Bird Dipper-Type Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket drive is vulnerable to jamming by rags, debris, etc.
2. Unit provides a rigid obstruction to flow.
3. Unit should operate over full range of flows.
4. Movement of solids could jam unit.
5. No automatic starter; no self cleaning features.
6. Collects fixed size aliquots paced by built-in timer or external flow meter and composits them in a suitable container.
7. Does not appear well suited for collecting either floatables or coarser bottom solids.
8. No sample collector provided.
9. Unit is capable of manhole operation.
10. Unit is not weatherproof; cannot withstand total immersion.
11. Unit is not suitable for prolonged operation in freezing ambients.
12. Unit would appear impractical for very long lifts (say above 60 feet).

Designation:	PROTECH MODEL CG-125
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-3854
Sampler Intake:	Plastic sampling chamber (about 2" diameter) with two rows of 1/8" diameter ports around the circumference. Weighted bottom caps are available to keep the intake screen off the bottom.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Standard maximum is 32 feet.
Line Size:	1/4" O.D.
Sample Flow Rate:	Less than 1/2 gpm; depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volumes of 25, 50, 75 or 100 ml; sample composited in suitable container, 1 1/2-gallon jug available.
Controls:	Sampling frequency is determined by metering gas pressure (via a rotometer with a vernier needle valve and two float balls) into a surge tank until a preset pressure (normally 15 psi) is reached, whereupon a pressure controller releases the gas (a 2 psi differential) to the sample chamber forcing the sample up to the sample bottle and blowing the lines clear. The higher the gas flow rate the higher the sampling frequency. Sampling frequency is adjustable from 30 seconds to over 30 minutes.
Power Source:	Three 1-pound cans of refrigerant on a common manifold inside the case is standard; compressed air or nitrogen can also be used.

Sample Refrigerator:	None in portable model. Stationary models have automatic refrigerated sample compartments.
Construction Materials:	All components in sampling train are TFE resins, PVC, and nylon. Case is aluminum, gas valves and fittings are of brass and copper.
Basic Dimensions:	11"W x 9"D x 15"H standard; 18" deep case large enough to hold a 1 1/2 gallon sample container and winterizing kit is available for portable models.
Base Price:	$583 for basic unit including 50 ml sample chamber, 6 cans of refrigerant, and two 20-foot lengths of tubing. Add $60 for deep case; $140 for winterizing kit; $10 for 100 ml sample chamber. CG-125S is version in upright cabinet for fixed indoor station operation with refrigerated sample storage at $1,650; in outdoor, weatherproof winterized cabinet price is $2,310.
General Comments:	Portable model is explosion proof, no battery or electrical power is required. Manufacturer claims unit will sample up to 1/8" diameter solids. Check valve in sample chamber is self-cleaning. Self-cleaning feature is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle. A flow splitter provides 1 to 2, 1 to 1, or 2 to 1 ratio of sample flow to waste return flow. Three cans of refrigerant will operate the sampler from 3 to 5 days in continuous operation. Winterizing is accomplished using strip heaters operated by an automatic temperature control. Case dimensions of stationary models are 29 1/2"W x 25 1/2"D x 48"H on 12" legs.

Protech Model CG-125 Evaluation

1. Sampling train is unobstructed 1/4" O.D. passageway which will pass small solids. No pump to clog.

2. Sampling chamber normally rests on a weighted cap on sewer invert. Unless clamped in place, it offers no rigid obstruction to flow.

3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of solids in flow could affect position of sampling chamber and erode plastic lines if flow is deep enough.

5. No automatic starter. A self-cleaning feature of sorts in the sampling chamber is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle.

6. Collects spot samples at preset time intervals and composits them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. No refrigeration available in the portable version. Stationary units have automatic, refrigerated sample compartments. Cross contamination appears likely.

9. Portable unit is designed for manhole operation.

10. Case is weatherproof but will not withstand total immersion.

11. Can operate in freezing ambients if fitted with optional winterizing kit.

12. Upper lift limit of 32 feet does not pose a great restriction on operating head conditions.

Designation: PROTECH MODEL CG-125FP

Manufacturer:
Protech, Inc.
Roberts Lane
Malvern, Pennsylvania 19355
Phone (215) 644-3854

Sampler Intake: Plastic sampling chamber (about 2" diameter) with two rows of 1/8" diameter ports around the circumference. Weighted bottom caps are available to keep the intake screen off the bottom.

Gathering Method: Forced flow due to pneumatic ejection.

Sample Lift: Standard maximum is 32 feet.

Line Size: 1/4" O.D.

Sample Flow Rate: Less than 1/2 gpm; depends upon pressure setting and lift.

Sample Capacity: Sample chamber volumes of 25, 50, 75 or 100 ml; sample composited in suitable container, 1 1/2-gallon jug available.

Controls: Can take samples at preset time intervals in same way as Model CG-125. For flow proportional sampling a normally closed, solenoid operated valve in the gas inlet opens momentarily on receiving an impulse from an external flow registering device. The sampling frequency is determined by the frequency and duration of these impulses and the rotometer setting. Thus the intermittent flow signal impulses are translated into fluidic impulses that are accumulated in the surge tank which serves as a totalizer. If the flow proportional signal is supplied by a totalizer and it is desired to take one sample per impulse, a solid state timer is available which will hold the solenoid open long enough to accumulate the necessary pressure.

Power Source: 115V ac or 6V dc; three 1-pound cans of refrigerant on a common manifold inside the case is standard; compressed air or nitrogen can also be used.

Sample Refrigerator: None

Construction Materials: All components in sampling train are TFE resins, PVC, and nylon. Case is aluminum, gas valves and fittings are of brass and copper.

Basic Dimensions: 11"W x 9"D x 15"H standard. 18" deep case large enough to hold a 1 1/2 gallon sample container and winterizing kit is available. Portable.

Basic Price: $693 for basic unit including 50 ml sample chamber, 6 cans of refrigerant, and two 20-foot lengths tubing. Add $60 for deep case; $140 for winterizing kit; $10 for 100 ml sample chamber; $205 for solid state timer.

General Comments: Basically a flow proportional version of Model CG-125. Completely portable in battery version. Control solenoid is certified by UL for use in hazardous areas.

Protech Model CG-125FP Evaluation

1. Sampling train is unobstructed 1/4" O.D. passageway which will pass small solids. No pump to clog.
2. Sampling chamber normally rests on weighted cap on sewer invert. Unless clamped in place, it offers no rigid obstruction to flow.
3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.

4. Movement of solids in flow could affect position of sampling chamber and erode plastic lines if flow is deep enough.
5. No automatic starter. A self cleaning feature of sorts in the sampling chamber is accomplished by the two-way flushing action which occurs during each filling and pressurizing cycle.
6. Collects spot samples at either preset time intervals or paced by an external flow meter and composits them in a suitable container.
7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.
8. No refrigeration available. Cross contamination appears likely.
9. Unit is designed for manhole operation.
10. Case is weatherproof but will not withstand total immersion.
11. Can operate in freezing ambients if fitted with optional winterizing kit.
12. Upper lift limit of 32 feet does not pose a great restriction on operating head conditions.

Designation	PROTECH MODEL CG-150
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-3854
Sampler Intake:	Plastic sampling chamber (about 2" diameter) with two rows of 1/8" diameter ports around the circumference. Weighted bottom caps are available to keep the intake screen off the bottom.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Standard maximum is 32 feet.
Line Size:	1/4" O.D.
Sample Flow Rate:	Less than 1/2 gpm; depends upon pressure setting and lift.
Sample Capacity:	Sample chamber volumes of 25, 50, 75 or 100 ml; sample composited in suitable container, 1 1/2-gallon jug available.
Controls:	Clock timer mode: Adjustable cams turned by a 7-day spring-wound clock actuate a valve in the compressed gas supply line to control sampling for an adjustable time period once every hour or every 8 hours over a 24 hour or 7 day period. Adjustable time-off, time-on plus automatic start-stop operation is a standard feature. Flow proportional mode: Same basic principle as Model CG-125FP.
Power Source:	Three 1-pound cans of refrigerant on a common manifold inside the case is standard; compressed air or nitrogen can also be used. Portable version uses 6V battery; stationary models use 115V ac.

Sample Refrigerator: None in portable models. Stationary models have automatic refrigerated sample compartments.

Construction Materials: All components in sampling train are TFE resins, PVC, and nylon. Case is aluminum, gas valves and fittings are of brass and copper.

Basic Dimensions: Portable - 11"W x 18"D x 15"H. Stationary - 27"W x 25 1/2"D x 49 1/2"H.

Base Price: $895 for basic portable unit including 50 ml sampling chamber, 6 cans of refrigerant, deep case, and two 20-foot lengths of tubing. Stationary unit is $1,850 in indoor cabinet and $2,510 in weatherproof outdoor cabinet.

General Comments: Similar to Model CG-125FP with addition of 7-day clock and automatic start-stop.

Protech Model CG-150 Evaluation

1. Sampling train is unobstructed 1/4" O.D. passageway which will pass small solids. No pump to clog.
2. Sampling chamber normally rests on weighted cap on sewer invert. Unless clamped in place, it offers no rigid obstruction to flow.
3. Sampling chamber will fill immediately following discharge of previous aliquot. Circulation of flow through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of the next triggering signal. Representativeness is also questionable at high flow rates.
4. Movement of solids in flow could affect position of sampling chamber and erode plastic lines if flow is deep enough.
5. Has automatic start-stop. A self cleaning feature of sorts in the sampling chamber is accomplished by the

two-way flushing action which occurs during each filling and pressurizing cycle.

6. Collects spot samples at either preset timer intervals or paced by an external flow meter and composits them in a suitable container.
7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.
8. No refrigeration in portable version; stationary units have automatic refrigerated sample compartments. Cross contamination appears likely.
9. Portable unit is designed for manhole operation.
10. Case is weatherproof but will not withstand total immersion.
11. Can operate in freezing ambients if fitted with optional winterizing kit.
12. Upper lift limit of 32 feet does not pose a great restriction on operating head conditions.

Designation:	PROTECH MODEL CEL-300
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsylvania 19355 Phone (215) 644-3854
Sampler Intake:	Plastic cylindrical (about 4" diameter x 8" long) screen perforated with 1/8" diameter ports over pump inlet.
Gathering Method:	Forced flow from submersible pump.
Sample Lift:	Standard maximum is 32 feet.
Line Size:	1/2" I.D. inlet hose.
Sample Flow Rate:	1 to 2 gpm recommended.
Sample Capacity:	Aliquot volume is a function of the preset diversion time; 1 1/2 gallon composite container is standard.
Controls:	Unit operates on continuous-flow principle, returning the uncollected sample to waste. Sample is pumped through a non-clogging flow-diverter type chamber. Upon receiving a signal from either an external flow registering device or the built-in timer, the unit diverts the flow for a preset period of time (adjustable from 0.06 to 1.0 second) to the sample container. When operating in the timed sampling mode, the sampling frequency can be set for 1, 2, or 5 minutes. When operating in the flow-proportional mode the sampler may accept either a timed pulse signal which can be accumulated (totalized) by the built-in timer, or a single totalized signal whereupon the sampler will be fired directly.
Power Source:	115V ac

Sample Refrigerator: None in portable model. Stationary models have automatic refrigerated sample compartment.

Construction Materials: Sampling train is PVC, nylon, stainless steel, and TFE resins; case is aluminum.

Basic Dimensions: Portable - 11"W x 18"D x 15"H. Stationary - 27"W x 25 1/2"D x 49 1/2"H.

Base Price: $1,450 including 36' of 1/2" I.D. inlet hose, 20' of 1" I.D. waste return hose, clamps, submersible pump and motor. Stationary model is $2,250 in indoor cabinet and $2,910 in weatherproof, winterized outdoor cabinet.

General Comments: Orbital magnetic drive submersible pump is impeller type, seal-less, epoxy-clad hermetically sealed. For applications where sample lift is relatively low and high pump output is unnecessary a by-pass kit is available to reduce flow through diverter chamber to 1 to 2 gpm.

A Model CEG-200 which has timing similar to CEL-300 but sample taken with pressure operated submersible chamber as in Model CG-125 but requiring external pressure source is available at $1,350 in portable version, $1,950 in stationary indoor case, and $2,610 in outdoor winterized case.

Protech Model CEL-300 Evaluation

1. Large sampling screen chamber over pump inlet can tolerate blockage of a number of ports and still function. Pump and tubing should be free from clogging.
2. Submersible pump and screen present an obstruction to the flow.

3. Should be capable of operation over the full range of flow conditions.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. No automatic starter since designed for continuous flow. Continuous flow serves a self cleaning function of all except line from diverter to sample bottle.

6. Collects spot samples paced either by built-in timer or external flow meter and composits them in a suitable container.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. No refrigeration available in portable version. Stationary units have automatic refrigerated sample compartment. Cross contamination should not be too great.

9. Portable unit is designed for manhole operation.

10. Cannot withstand total immersion.

11. Can operate in freezing ambients if fitted with optional winterizing kit.

12. Upper lift limit of 32 feet does not pose a great restriction on operating head conditions.

Designation:	PROTECH MODEL DEL-240S
Manufacturer:	Protech, Inc. Roberts Lane Malvern, Pennsyvlania 19355 Phone (215) 644-3854
Sampler Intake:	Plastic cylindrical (about 4" diameter x 8" long) screen perforated with 1/8" diameter ports over pump inlet.
Gathering Method:	Forced flow from submersible pump.
Sample Lift:	Standard maximum is 32 feet.
Line Size:	1/2" I.D. inlet hose.
Sample Flow Rate:	1 to 2 gpm recommended.
Sample Capacity:	Aliquot volume is function of preset diversion time; can take 24 individual samples of 100 ml each or one composite sample of 1 1/2-gallons.
Controls:	Similar to Model CEL-300 with addition of 7-day clock allowing sampling at 30 minute intervals and time-on, time-off programming.
Power Source:	115V ac
Sample Refrigerator:	Automatic refrigerated sample compartment.
Construction Materials:	Sampling train is PVC, nylon, stainless steel, and TFE resins; case is aluminum.
Basic Dimensions:	30"W x 32"D x 60"H on 12" legs; stationary.
Base Price:	$5,606.
General Comments:	Unit is basically a CEL-300S in outdoor case with provisions for collecting 24 discrete samples as well as a composite sample.

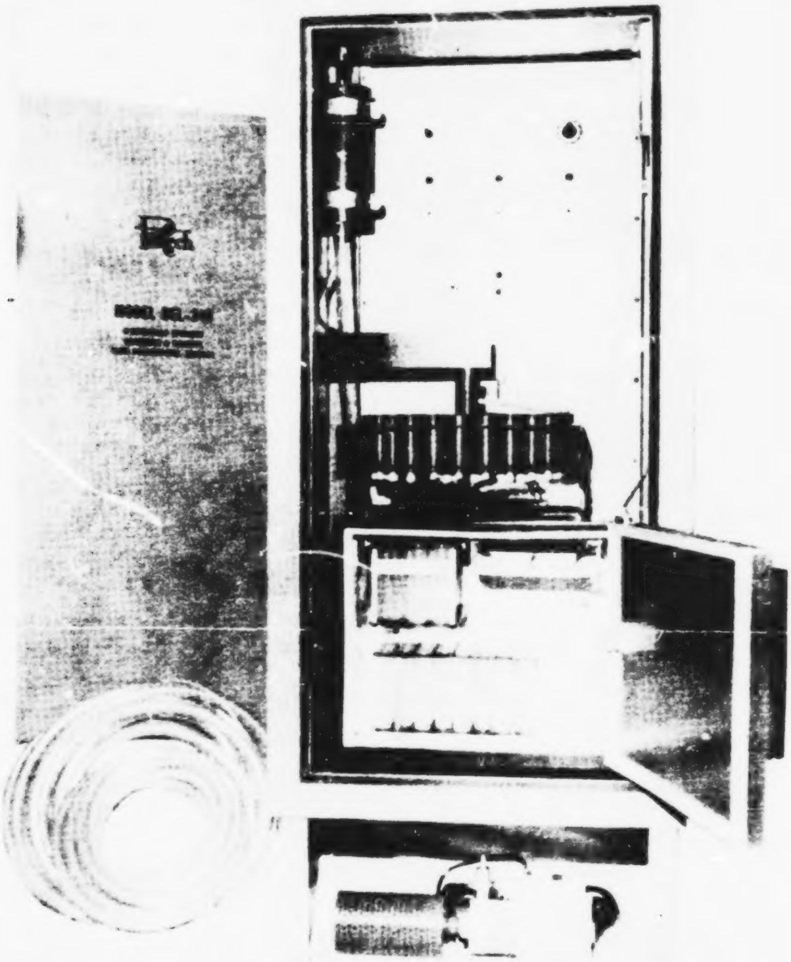

Figure 9. Protech Model DEL-240S Sampler

Photograph courtesy of Protech, Inc.

Protech Model DEL-240S Evaluation

1. Large sampling screen chamber over pump inlet can tolerate blockage of a number of ports and still function. Pump and tubing should be free from clogging.

2. Submersible pump and screen present an obstruction to the flow.

3. Should be capable of operation over the full range of flow conditions.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. 7-day clock can provide programmed automatic start-stop. Continuous flow serves a self cleaning function of all except line from diverter to sample bottle.

6. Collects spot samples paced either by built-in timer or external flow meter and either composits them in a suitable container or collects them discretely in 24 individual containers.

7. Appears unsuitable for collection of either floatable materials or coarser bottom solids.

8. Automatic refrigerated sample compartment. Cross contamination should not be too great.

9. Unit is not designed for manhole operation.

10. Cannot withstand total immersion.

11. Can operate in freezing ambients.

12. Upper lift limit of 32 feet does not pose a great restriction on operating head conditions.

Designation:	QCEC MODEL CVE
Manufacturer:	Quality Control Equipment Company 6139 Fleur Drive Des Moines, Iowa 50315 Phone (515) 285-3091
Sampler Intake:	End of suction line installed to suit by user.
Gathering Method:	Suction lift from vacuum pump.
Sample Lift:	20 foot maximum.
Line Size:	1/4" I.D.
Sample Flow Rate:	Depends upon lift.
Sample Capacity:	Adjustable aliquots of from 20 to 50 ml are composited in a 1/2-gallon jug.
Controls:	Sampling cycles can either be started at fixed, selected intervals by a built-in timer or in response to signals from an external flow meter.
Power Source:	115V ac standard; 12V dc optional.
Sample Refrigerator:	Standard model has insulated case with built-in ice chamber; automatic refrigeration is available as an option.
Construction Materials:	Sampling train is tygon, polypropylene, polyethylene, and glass; case is fiberglass.
Basic Dimensions:	15"W x 15"D x 24"H; portable.
Base Price:	$520 for base unit with timer only. Add $160 for counter to allow pacing by external flow meter, $225 for mechanical refrigeration, $35 for electric heater.

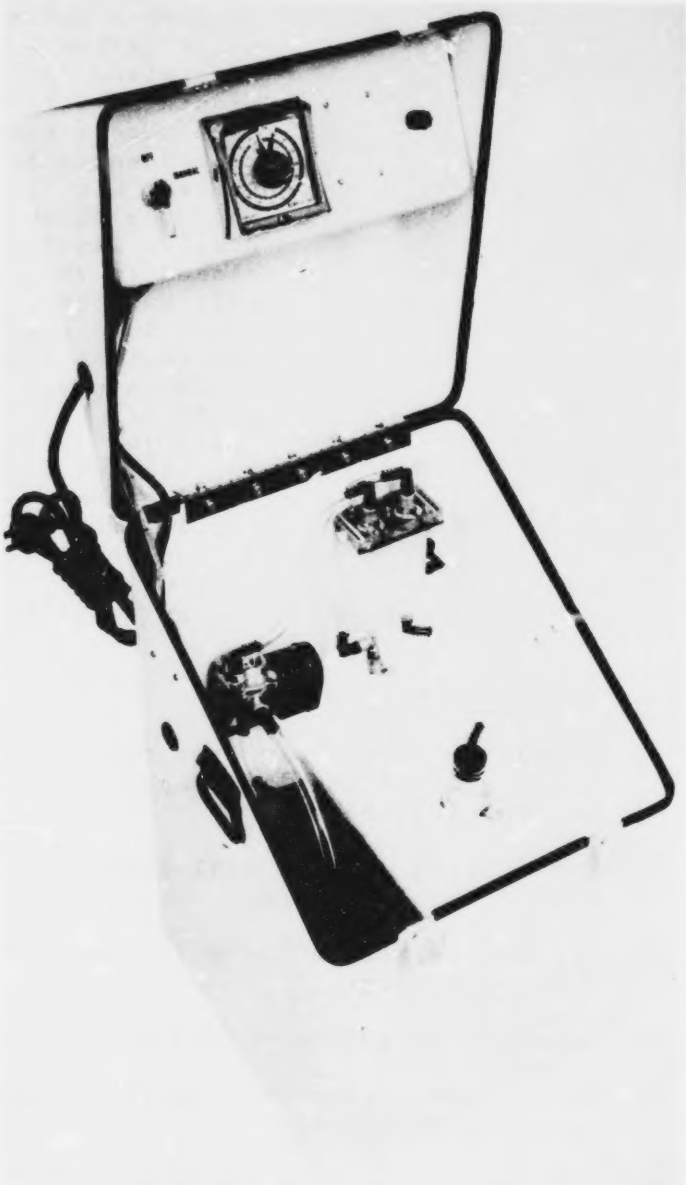

Figure 10. Quality Control Equipment Company Model CVE Sampler

Photograph courtesy of Quality Control Equipment Company

General Comments:

Unit was developed by Dow Chemical and is manufactured under license. It uses a patented vacuum system which delivers a volumetrically controlled sample on signal. Liquid is lifted through suction tube into a sample chamber (which is connected to the sample container) with a float check valve. When the chamber is filled to the desired level it is automatically closed to vacuum, the pump shuts off, and the sample is forcibly drawn into the sample container. The suction line drains by gravity to the source. An option provides an 80 psi blow-down of the sampling train just prior to sampling assuring that no old material remains in the submerged lower end of the suction tube, helps clean the lines of any accumulations which might clog or plug, and provides a fresh air purge of the entire system.

QCEC Model CVE Evaluation

1. Should be relatively free from clogging due to lack of bends and fittings in sample train and optional 80 psi purging feature.

2. Obstruction of flow will depend upon way user mounts end of sampling tube.

3. Should operate fairly well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. Optional purge serves a self-cleaning function.

6. Can collect samples paced by either built-in timer or external flow meter and composite them in a suitable container. Representativeness of sample will depend upon user mounting of intake tube.

7. Unit does not appear suitable for collection of floatables or coarser bottom solids.

8. Standard unit has insulated sample container with ice chamber; automatic refrigeration is optional. Appears to offer good sample protection and freedom from precontamination.

9. Unit would appear to function satisfactorily in a manhole environment.

10. Cannot withstand total immersion.

11. Thermostatically controlled heater is available for applications in freezing ambients.

12. Maximum lift of 20 feet does not place too severe a restriction on use of the unit.

Designation: QCEC MODEL E

Manufacturer: Quality Control Equipment Company
613 Fleur Drive
Des Moines, Iowa 50315
Phone (515) 285-3091

Sampler Intake: Dipping bucket.

Gathering Method: Mechanical; dipper on sprocket-chain drive.

Sample Lift: To suit; manufacturer claims no reasonable limit to working depth.

Line Size: Not applicable.

Sample Flow Rate: Not applicable.

Sample Capacity: Dipping bucket holds 2 ounces; user supplies sample composite container to suit.

Controls: Sampling cycles can either be started at fixed, selected intervals by a built-in timer or in response to signals from an external flow meter.

Power Source: 115V ac

Sample Refrigerator: None

Construction Materials: Dipper is stainless steel; sprockets and chain are corrosion-resistant cast iron (stainless available), supports are provided by user.

Basic Dimensions: Upper unit is 8"W x 15 1/2"D x 14"H; lower unit is 3" x 4 1/2".

Base Price: $875 plus $20 per foot beyond 6'; add $375 for stainless steel sprockets and chain plus $40 per foot beyond 6'.

General Comments: Manufacturer states that unit was designed as a permanently installed sampler for the most difficult applications such as packing houses, steel mills, pulp mills, and municipal applications. Unit must be custom installed by user. Minimum water depth required is 4".

QCEC Model E Evaluation

1. Clogging of sampling train is unlikely; however, the exposed chain-sprocket drive is vulnerable to jamming by rags, debris, etc.
2. Unit provides a rigid obstruction to flow.
3. Unit should operate over full range of flows.
4. Movement of solids could jam or physically damage unit.
5. No automatic starter; no self cleaning features.
6. Collects fixed size aliquots paced by built-in timer or external flow meter and composits them in a suitable container.
7. Does not appear well suited for collecting either floatables or coarser bottom solids.
8. No sample collector provided.
9. Unit is capable of manhole operation.
10. Unit is weatherproof; cannot withstand total immersion.
11. Unit is not suitable for prolonged operation in freezing ambients.
12. Unit would appear impractical for very long lifts (say above 60 feet).

Designation:	SERCO MODEL NW-3
Manufacturer:	Sonford Products Corporation 100 East Broadway, Box B St. Paul Park, Minn. 55071 Phone (612) 459-6065
Sampler Intake:	Twenty four 1/4" I.D. vinyl sampling lines are connected to individual ports in a stainless steel sampling head (approx. 4" dia) and protected by a stainless steel shroud.
Gathering Method:	Suction lift from vacuum in evacuated sample bottles.
Sample Lift:	3 feet standard; sample size reduced as lift increases; 8 to 10 feet appears practical upper limit.
Line Size:	1/4" I.D.
Sample Flow Rate:	Varies with filling time, atmospheric pressure, bottle vacuum, sample lift, etc.
Sample Capacity:	24-16 ounce French square glass bottles are provided. Sample sizes up to 400 ml can be obtained depending upon lift, bottle vacuum and atmospheric pressure; 200 ml is typical.
Controls:	A spring driven clock via a changeable gearhead rotates an arm which trips line switches at a predetermined time interval triggering sample collection. Sampling intervals of 2, 3, or 8 hours and 5, 10, or 30 minutes are available in addition to the standard 1 hour interval.
Power Source:	Spring driven clock.
Sample Refrigerator:	Has ice cavity for cooling.

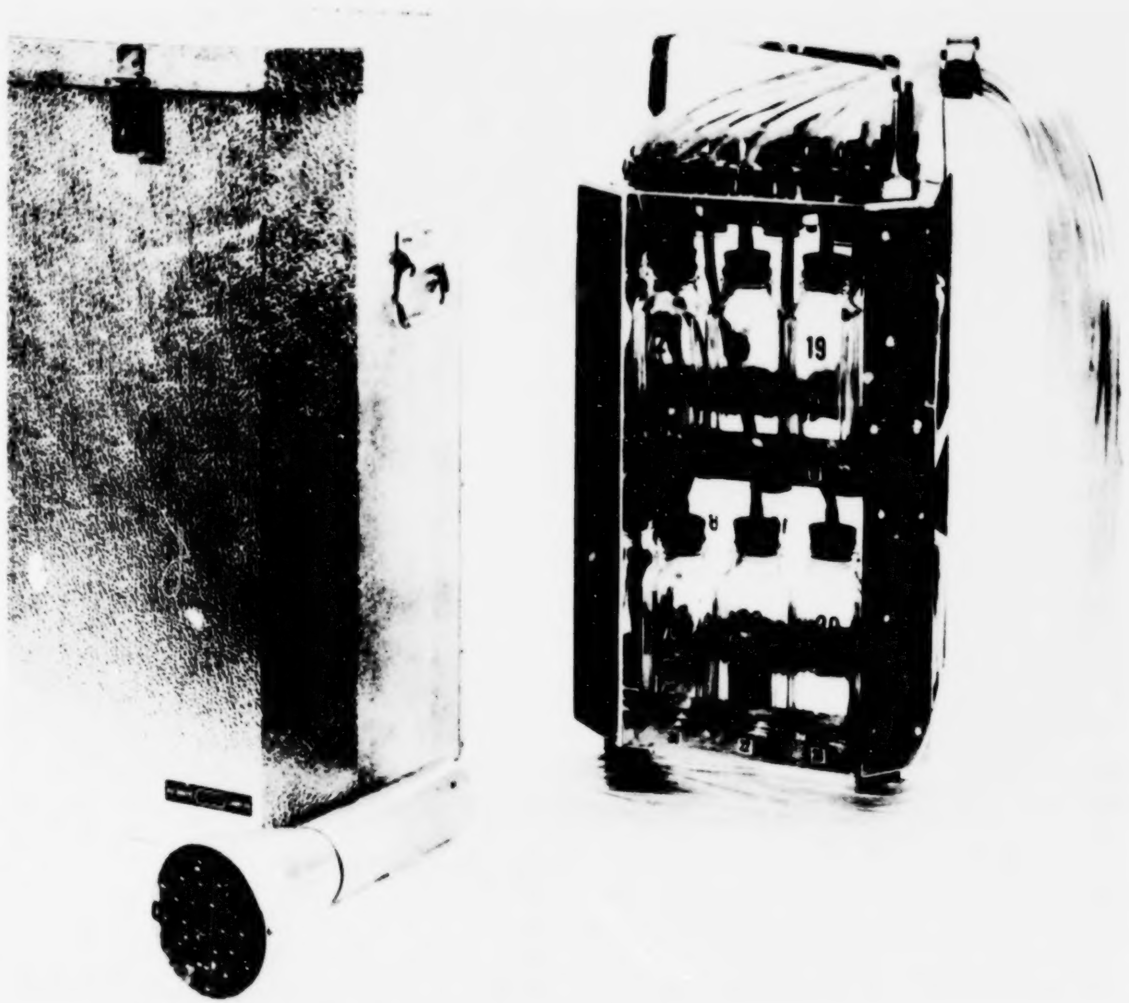

Figure 11. SERCO Model NW-3 Sampler

Photograph courtesy of Sonford Products Corp.

Construction Materials: Aluminum case with rigid polystyrene insulation; aluminum bottle rack; glass bottles with rubber stoppers and rubber lines through switch plate, plastic connectors and vinyl lines to stainless steel sampling head.

Basic Dimensions: 15 1/2"W x 15 1/2"D x 26 3/4"H; empty weight is 55 pounds; portable.

Base Price: $920 including vacuum pump.

Serco Model NW-3 Evaluation

1. Sampling head is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is an unobstructed 1/4 inch passageway which will pass small solids. No pump to clog.

2. Sampling head and shroud are simply dangled in the flow stream to be sampled. No rigid obstruction.

3. Low sampling velocities make representativeness of samples questionable at high flow rates. Length of protective shroud limits immersion to about 1 foot before vinyl sampling tubes are exposed to flow.

4. Sampling head would appear to be vulnerable to clogging if in bed load. Stainless steel shroud offers good protection against movement of solids in flow stream.

5. Optional automatic starter available which allows remote starting by either clock or float mechanism. Otherwise must be started manually. No self cleaning features. Proper cleaning of all 24 sampling lines would be difficult and time consuming in the field.

6. Collects discrete samples at preset times.

7. Appears unsuitable for collection of samples of either floatable materials or coarser bottom solids.

8. Provision for ice cooling affords some sample protection for a limited time. Limited lift may require

placing sampler case in a vulnerable location. Use of individual sampling lines eliminates cross contamination possibility.

9. Unit will pass through a 20" circle. Case has base opening where sampling line bridle emerges. Should be capable of manhole operation.

10. Case will fill with fluid if submerged. Spring clock and drive mechanism then becomes vulnerable, especially if fluid contains solids.

11. No standard provision for heating case. Freezing of sampling lines appears a distinct possibility.

12. Practical upper lift limit of 8 to 10 feet poses restrictions on operating head conditions.

Designation:	SERCO MODEL TC-2
Manufacturer:	Sonford Products Corporation 100 East Broadway, Box B St. Paul Park, Minn. 55071 Phone (612) 459-6065
Sampler Intake:	Provided by user; sampler has standard 2" pipe inlet.
Gathering Method:	External head to provide flow through a sample reservoir from which a mechanical arm actuated by an air cylinder with a dipper cup extracts a sample aliquot and transfers it to a funnel where it is gravity fed to a composite bottle.
Sample Lift:	Not applicable.
Line Size:	Smallest line in sampling train is the one connecting the funnel to the tube leading to the sample bottle; it appears to be about 3/4".
Sample Flow Rate:	Recommended flow rate through sampler is 10 to 15 gpm. Reservoir is designed so that sufficient velocity and turbulence will prevent settling or separation.
Sample Capacity:	Sampling dippers are available in either 10 or 20 ml capacity; a 2-gallon sample composite container is provided.
Controls:	Takes samples either on signal from a preset timer or from signals originating from an external flow meter.
Power Source:	115V ac electrical plus low pressure plant air.
Sample Refrigerator:	Automatic refrigeration unit thermostatically controlled to maintain sample temperature at 4° to 10°C.

Construction Materials:	Sampling arm is all brass and stainless steel; dipper cup is plastic; cabinet is stainless steel with zinc plated framing and porcelain interior.
Basic Dimensions:	38 1/4"W x 24 1/4"D x 34 1/2"H plus sampling arm which extends up 23 1/2" and back about a foot. Designed for fixed installation.
Base Price:	$2,495.
General Comments:	A permanent installation for continuous composite sampling. The actual sampling device is simply an open cup which is large enough to permit sampling all sizes of suspended solids normally encountered in wastewater flows. Because the cup is emptied by turning it over completely, the entire sample is removed and there is little likelihood of solids being retained in the cup.

Serco Model TC-2 Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Designed for continuous operation; no automatic starter. Continuous flow serves a self cleaning function and should minimize cross-contamination.
6. Can collect either flow proportional composite or fixed time interval composite. Representativeness of sample will be a function of sampling intake which is not a part of this unit.
7. Collection of floatables and coarser bottom solids will depend upon design of sampling intake.

8. Automatic refrigeration maintains samples at 4° to 10°C. Offers good sample protection and freedom from precontamination.

9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Not designed for use in freezing ambient conditions.

12. Operating head is provided by user.

Designation:	SIGMAMOTOR MODEL WA-1
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 25 foot long suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sampler Lift:	22 foot maximum lift.
Line Size:	1/8" I.D.
Sampler Flow Rate:	60 ml per minute.
Sample Capacity:	Adjustable size aliquots of from 60 to 1,800 ml are composited in a 2 1/2 gallon sample container.
Controls:	Built-in timer triggers unit once every 30 minutes. Model WA-2 has an adjustable timer allowing sampling interval to be set from 1 to 30 minutes.
Power Source:	115V ac. Model WD-1 comes with a N. Cad battery pack and charger.
Sample Refrigerator:	None. Model WA-2R has an automatic refrigeration unit for cooling sample compartment.
Construction Materials:	Sample train is tygon and polyethylene; case is ABS plastic.
Basic Dimensions:	WA-1, WA-2, WD-1, WD-2 - 13 1/2"W x 10"D x 14"H; WA-2R - 21 1/2"W x 21 1/4"D x 34"H; weights are WA-1 18 pounds, WA-2 19 pounds, WD-1 28 pounds, WD-2 29 pounds, WA-2R 90 pounds; all portable.
Base Price:	$400 WA-1; $600 WD-1 $450 WA-2; $650 WD-2; $700 WA-2R

General Comments: Charge time for battery operated models is 16 hours. On model WA-2R the pump automatically purges the tubing at the end of each sampling cycle to help prevent bacterial growth in the line.

Sigmamotor Model WA-1 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line; the peristaltic pump can tolerate solids but the 1/8" I.D. tubing size is rather small.
2. Obstruction of flow will depend upon user mounting of intake line.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.
4. Movement of solids within the fluid flow should not affect operation adversely.
5. No automatic starter. Only the refrigerated model has an automatic purging feature for self-cleaning.
6. Unit takes fixed time interval samples paced by a built-in timer and composits them in a suitable container.
7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.
8. Units offer reasonable sample protection; a refrigerated model is available to maintain sample at a preset temperature.
9. Unit appears capable of manhole operation.
10. Unit cannot withstand total immersion.
11. Unit cannot withstand freezing ambients.
12. 22 foot maximum lift does not place a great operating restriction on unit. All but the refrigerated model will pass through a standard manhole.

Designation:	SIGMAMOTOR MODEL WA-3
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 25 foot long suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	22 foot maximum lift.
Line Size:	1/4" I.D.
Sample Flow Rate:	50 ml per minute.
Sample Capacity:	Adjustable size aliquots of from 60 to 1,800 ml are composited in a 2 1/2 gallon sample container.
Controls:	Built-in timer triggers unit once every 30 minutes. Model WA-4 has an adjustable timer allowing sampling interval to be set from 1 to 30 minutes.
Power Source:	115V ac. Model WD-3 comes with a N. Cad battery pack and charger.
Sample Refrigerator:	None
Construction Materials:	Sample train is tygon and polyethylene; case is ABS plastic.
Basic Dimensions:	13 1/2"W x 20"D x 14"H; weights are WA-3 22 pounds, WA-4 23 pounds, WD-3 28 pounds, WD-4 29 pounds; all portable.
Base Price:	$650 WA-3; $850 WD-3 $700 WA-4; $900 WD-4
General Comments:	Charge time for battery operated models is 16 hours. Manufacturer recommends this model for sampling streams with long fibers and larger particles.

Sigmamotor Model WA-3 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line; the unobstructed 1/4" I.D. sampling line and the peristaltic pump should tolerate solids fairly well.
2. Obstruction of flow will depend upon user mounting of intake line.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.
4. Movement of solids within the fluid flow should not affect operation adversely.
5. No automatic starter; no self-cleaning feature.
6. Unit takes fixed time interval samples paced by a built-in timer and composits them in a suitable container.
7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.
8. Units offer reasonable sample protection, but offers no refrigeration.
9. Unit appears capable of manhole operation.
10. Unit cannot withstand total immersion.
11. Unit cannot withstand freezing ambients.
12. 22 foot maximum lift does not place a great operating restriction on unit.

Designation:	SIGMAMOTOR MODEL WDPP-2
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 25 foot long suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	22 foot maximum lift.
Line Size:	1/8" I.D.
Sample Flow Rate:	60 ml per minute.
Sample Capacity:	Adjustable size aliquots of from 36 to 480 ml are composited in a 2 1/2 gallon sample container.
Controls:	System responds to a switch closure from an external flow meter and takes an adjustable size sample. Model WDP-2 varies the number of samples in response to a varying signal from a user supplied transmitter. The unit will deliver a 30 second sample (nominally 30 ml) every 4 minutes at maximum signal strength, every 8 minutes at one-half signal strength, etc.
Power Source:	115V ac or 12V dc; unit comes with a N. Cad battery pack and charger.
Sample Refrigerator:	None standard.
Construction Materials:	Sample train is tygon and polyethylene; case is ABS plastic.
Basic Dimensions:	13 1/2"W x 10"D x 14"H; weighs 25 pounds; portable.
Base Price:	$680 WDPP-2; $770 WDP-2
General Comments:	Charge time for batteries is 16 hours.

Sigmamotor Model WDPP-2 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line; the peristaltic pump can tolerate solids but the 1/8" I.D. tubing size is rather small.

2. Obstruction of flow will depend upon user mounting of intake line.

3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.

4. Movement of solids within the fluid flow should not affect operation adversely.

5. No automatic starter; no self-cleaning feature.

6. Unit takes flow proportional samples paced by an external flow meter and composits them in a suitable container.

7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.

8. Units offer reasonable sample protection, but offer no refrigeration.

9. Units appear capable of manhole operation.

10. Units cannot withstand total immersion.

11. Unit cannot withstand freezing ambients.

12. 22 foot maximum lift does not place a great operating restriction on unit.

Designation	SIGMAMOTOR MODEL WM-1-24
Manufacturer:	Sigmamotor, Inc. 14 Elizabeth Street Middleport, New York 14105 Phone (716) 735-3616
Sampler Intake:	End of 25 foot long suction tube installed to suit by user.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	22 foot maximum lift.
Line Size:	1/8" I.D.
Sample Flow Rate:	60 ml per minute.
Sample Capacity:	Unit takes 24 discrete 450 ml samples.
Controls:	Sampling frequency adjustable from one every 10 minutes to one every hour. External flow meter pacing available on special order.
Power Source:	115V ac. Model WM-2-24 comes with a N. Cad battery pack and charger.
Sample Refrigerator:	None. WM-1-24R has an automatic refrigeration unit for cooling sample compartment.
Construction Materials:	Sample train is tygon and polyethylene; case is ABS plastic.
Basic Dimensions:	WM-1-24; WM-2-24 - 14 1/2"W x 13"D x 24 1/2"H; WM-1-24R - 20"W x 21"D x 33 1/2"H; weights are WM-1-24 28 pounds, WM-2-24 36 pounds, WM-1-24R 125 pounds; all portable.
Base Price:	$1,050 WM-1-24; $1,200 WM-2-24; $1,525 WM-1-24R
General Comments:	Charge time for battery operated model is 16 hours. The pump automatically purges the tubing at the

end of each sampling cycle to help prevent bacterial growth in the line and minimize cross-contamination.

Sigmamotor Model WM-1-24 Evaluation

1. Obstruction or clogging will depend upon user installation of intake line; the peristaltic pump can tolerate solids but the 1/8" I.D. tubing size is rather small.
2. Obstruction of flow will depend upon user mounting of intake line.
3. Should operate reasonably well under all flow conditions, but fairly low intake velocity could affect representativeness of sample at high flow rates.
4. Movement of solids within the fluid flow should not affect operation adversely.
5. No automatic starter. Unit has an automatic purging feature for self-cleaning.
6. Unit takes 24 fixed interval samples paced by a built-in timer and deposits them in individual containers.
7. Unit does not appear suitable for collecting either floatables or coarser bottom solids.
8. Units offer reasonable sample protection; a refrigerated model is available to maintain sample at a preset temperature.
9. Units appear capable of manhole operation.
10. Units cannot withstand total immersion.
11. Unit cannot withstand freezing ambients.
12. 22 foot maximum lift does not place a great operating restriction on unit. All but the refrigerated model will pass through a standard manhole.

Designation:	SIRCO SERIES B/ST-VS
Manufacturer:	Sirco Controls Company 8815 Selkirk Street Vancouver, B.C. Phone 261-9321
Sampler Intake:	End of 25 foot sampling tube installed to suit by user.
Gathering Method:	Suction lift by vacuum pump.
Sample Lift:	Up to 22 feet vertical and 100 feet horizontal.
Line Size:	3/8" I.D.
Sample Flow Rate:	Depends upon lift.
Sample Capacity:	Sample volume is adjustable between 10 to 1000 ml; either composited in 2-, 3-, or 5-gallon jars or sequential in either 12 or 24 jars of either 1 pint or 1 quart capacity.
Controls:	"Metermatic" chamber (adjustable) controls sample volume. Available with built-in timer for preset time interval sampling or for connection to external flow meter for flow porportional sampling or both. Purge timer.
Power Source:	Either 110V ac or 12V dc lead zinc or nickel cadmium battery or combination.
Sample Refrigerator:	Available with thermostatically controlled refrigerated sample compartment.
Construction Materials:	PVC sampling tube, weatherproof steel enclosure standard; all stainless steel construction available.
Basic Dimensions:	A fairly large unit (about 20-30 cubic feet) that is not easily portable.

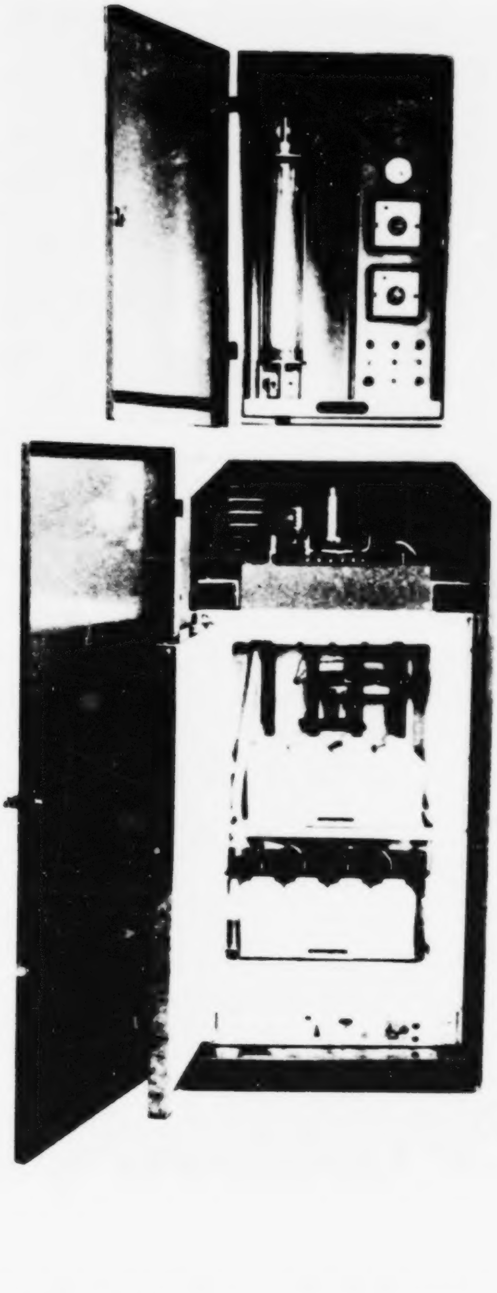

Figure 12. Sirco Series B/ST-VS Sampler

Photograph courtesy of Sirco Controls Company

Base Price:

$1,760 non-refrigerated composite sampler
$2,180 refrigerated composite sampler
$2,485 non-refrigerated 12 jar sequential
$2,670 non-refrigerated 24 jar sequential
$2,770 refrigerated 12 jar sequential
$2,950 refrigerated 24 jar sequential

General Comments:

Signal from flow meter or timer starts vacuum/compressor pump as well as purge timer. Compressor side of pump purges sample pick-up tube until purge timer times out. Sequence changes and vacuum side of pump evacuates metering chamber and draws sample in to the desired capacity. After obtaining the desired amount of sample, the compressor side of pump is used to forcibly discharge sample from metering chamber into sample collector.

Should plugging of the sample pick-up tube occur, an automatic timer switch uses the compressor side to blow out the tube. This sequence repeats itself as often as needed to obtain the exact amount of sample required. Purging also takes place before and after each sample is taken.

Manufacturer states this unit is especially designed to sample untreated raw sewage or high consistency industrial waste as it is capable of taking solids up to 3/8" in diameter including rags, fibers, and similar. The only wetted parts are the sample tubing and volume control chamber.

Sirco Series B/ST-VS Evaluation

1. Should be relatively free from clogging due to lack of bends and fittings in sample train and high pressure purging feature.

2. Obstruction of flow will depend upon way user mounts the end of the sampling tube.

3. Should operate well over the entire range of flow conditions.

4. Movement of solids should not hamper operation.

5. No automatic starter. Power purge serves a self-cleaning function.

6. Can collect external flow meter or built-in timer paced samples either sequential or composite. Representativeness of sample will depend upon user mounting of intake tube.

7. Unsuitable for collection of floatables or coarser bottom solids without specially designed intake by user.

8. Automatic refrigeration (adjustable temperature) available. Offers good sample protection and freedom from precontamination.

9. Not designed for confined space or manhole operation.

10. Cannot withstand total immersion.

11. Thermostatically controlled heaters and fans are available for applications in freezing ambients.

12. Maximum lift of 22 feet does not place too severe a restriction on use of the unit.

Designation: SIRCO SERIES B/IE-VS

Manufacturer:
Sirco Controls Company
8815 Selkirk Street
Vancouver, B.C.
Phone 261-9321

Sampler Intake: 2" I.D. guide pipe for sampling cup with perforations in lower end to maximum flow level.

Gathering Method: Mechanical; a weighted sampling cup is lowered through a guide pipe into the effluent by a hoist mechanism powered by a reversing gear motor. At the upper travel stop the cup empties sample into a sample container by gravity.

Sample Lift: Up to 200 feet.

Line Size: Smallest line in sampling train appears to be about 3/8" tube connecting collection funnel to sample reservoir.

Sample Flow Rate: Not applicable.

Sample Capacity: Sample cup has 100 ml capacity; either composited in 2-, 3-, or 5-gallon jars or sequential in either 12 or 24 jars of either 1 pint or 1 quart capacity.

Controls: Available with built-in timer for pre-set time interval sampling or for connection to external flow meter for flow proportional sampling or both.

Power Source: Either 110V ac or 12V dc lead zinc or nickel cadmium battery or combination.

Sample Refrigerator: Available with thermostatically controlled refrigerated sample compartment.

Construction Materials: PVC sampling cup and guide tube, weatherproof steel enclosure standard; all stainless steel construction available.

Basic Dimensions: About 3'W x 2'D x 5'H. Not easily portable.

Base Price:
$1,380 non-refrigerated composite sampler
$1,989 refrigerated composite sampler
$1,995 non-refrigerated 12 jar sequential
$2,185 non-refrigerated 24 jar sequential
$2,585 refrigerated 12 jar sequential
$2,850 refrigerated 24 jar sequential

General Comments: This unit was designed for high lift applications. According to the manufacturer it is not recommended for high consistency industrial effluent or raw sewage where large pieces of fiber, rags, papers, etc. are present.

Sirco Series B/IE-VS Evaluation

1. Cup in guide pipe appears susceptible to sticking and clogging. Guide pipe perforations are vulnerable to obstruction and clogging.

2. The 2" I.D. guide pipe must pass completely through the flow stream to be sampled presenting a serious rigid obstruction to flow.

3. Does not appear capable of uniform operation over full range of flow conditions.

4. Solids could collect in guide pipe and hamper cup travel.

5. No automatic starter. No self cleaning features.

6. Can collect flow meter or timer paced samples either sequential or composite. Representativeness of sample

will be dependent upon conditions at end of guide tube but appear highly variable and questionable.

7. Not suitable for collection of floatables or coarser bottom solids.

8. Automatic refrigerator (adjustable temperature) available. Offers good sample protection but vulnerable to cross contamination in sequential mode.

9. Not designed to operate in manholes.

10. Cannot withstand total immersion.

11. Thermostatically controlled heaters and fans are available for applications in freezing ambients.

12. 200 foot lift (or more) gives this unit virtually unrestricted use.

Designation: SIRCO SERIES B/DP-VS

Manufacturer: Sirco Controls Company
8815 Selkirk Street
Vancouver, B.C.
Phone 261-9321

Sampler Intake: Provided by user. Sampler has 2" inlet pipe.

Gathering Method: External head to provide flow through sampler and back to sewer. On signal a liquid diverter mechanism is energized for a preset number of seconds and sample is drawn into a metering chamber. After the desired amount of sample is obtained, a solenoid valve at the bottom of the metering chamber is actuated and the sample is discharged by gravity into the sample jar.

Sample Lift: Not applicable.

Line Size: Smallest line size appears to be about 3/8 inch tube leading to sample jar.

Sample Flow Rate: Depends upon user's installation; no recommended minimum.

Sample Capacity: Sample metering chamber adjustable from 50 to 500 ml; either composited in 2-, 3-, or 5-gallon jars or sequential in either 12 or 24 jars of either 1 pint or 1 quart capacity.

Controls: Available with built-in timer for pre-set time interval sampling or for connection to external flow meter for flow proportional sampling or both.

Power Source: Either 110V ac or 12V dc lead zinc or nickel cadmium battery or combination.

Sample Refrigerator:	Available with thermostatically controlled refrigerated sample compartment.
Construction Materials:	Sampling train is stainless steel and plastic; weatherproof steel enclosure standard; all stainless steel construction available.
Basic Dimensions:	About 3'W x 2'D x 5'H. Designed for fixed installation.
Base Price:	$1,550 non-refrigerated composite sampler $1,870 refrigerated composite sampler $2,190 non-refrigerated 12 jar sequential $2,360 non-refrigerated 24 jar sequential $2,460 refrigerated 12 jar sequential $2,640 refrigerated 24 jar sequential
General Comments:	This unit was designed for installations where the sampler must be some distance, say more than 100 feet, from the sample pick-up point. It is recommended by the manufacturer for treated sewage or final effluent.

Sirco Series B/DP-VS Evaluation

1. Diverter mechanism could be subject to clogging (manufacturer only recommends unit for treated sewage or final effluent). Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should be capable of operating over entire range of flow conditions.
4. Movement of solids should not hamper operation.

5. No automatic starter. Continuous flow serves a self-cleaning function and should reduce cross-contamination.

6. Can collect flow meter or timer paced samples either sequential or composite. Representativeness of sample will depend upon design of sampling intake which is not a part of this unit.

7. Unsuitable for collection of floatables or coarser bottom solids.

8. Automatic refrigerator (adjustable temperature) available. Offers good sample protection but vulnerable to slight cross-contamination in sequential mode.

9. Specifically designed for installation remote from sample pick-up point. Not suitable for manhole operation.

10. Cannot withstand total immersion.

11. Thermostatically controlled heater and fans are available for applications in freezing ambients.

12. Operating head is provided by user.

Designation: SIRCO MODEL PII-A

Manufacturer:
Sirco Controls Company
8815 Selkirk Street
Vancouver, B.C.
Phone 261-9321

Sampler Intake: End of 20 foot sampling tube installed to suit by user.

Gathering Method: Suction lift by vacuum pump.

Sample Lift: Up to 18 feet.

Line Size: 1/4" I.D.

Sample Flow Rate: Depends upon lift.

Sample Capacity: Sample volume adjustable between 10 and 200 ml; composited in 1-, 2-, or 3-gallon jar.

Controls: Adjustable chamber controls sample volume. Built-in timer allows adjusting sample cycle from 3 minutes to 40 hours.

Power Source: 12V dc lead zinc or nickel cadmium battery.

Sample Refrigerator: None

Construction Materials: PVC sampling tube and case.

Basic Dimensions: 12" diameter x 28"H not including battery case; weighs 50 pounds empty; portable.

Base Price: $1,387. Add $95 for heavy duty battery and case; add $182 for battery with charger; add $168 for N. Cad battery instead of standard battery.

General Comments: Signal from timer starts vacuum/compressor pump. Compressor side of pump purges sample intake tube, sequence changes and vacuum side of pump evacuates metering chamber and draws desired amount of sample.

Compressor side of pump then discharges sample into sample container. Should plugging of the sampling tube occur, the pump is switched to the compressor side to blow out the tube. This sequence is repeated until the desired amount of sample is collected. Purging also takes place before and after each sample is taken.

Manufacturer states that the unit is especially designed to sample untreated raw sewage or high consistency industrial waste containing rags, fibers, etc.

Sirco Model PII-A Evaluation

1. Should be fairly free from clogging due to lack of bends and fittings in sample train and high pressure purging feature.
2. Obstruction of flow will depend upon way user mounts the end of the sampling tube.
3. Should operate equally well under the entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. No automatic starter. Power purge serves a self cleaning function.
6. Can collect a composite of timer paced samples only. Representativeness of sample will depend upon user mounting of intake tube.
7. Unsuitable for collection of floatables or coarser bottom solids without special designed intake by user.
8. No refrigeration. Sample appears fairly well protected in case.
9. Designed to operate in manhole area.
10. Cannot be totally immersed.

11. Cannot withstand freezing ambient.

12. Maximum lift of 18 feet when coupled with small size allows considerable flexibility in use of the unit.

Designation:	SONFORD MODEL HG-4
Manufacturer:	Sonford Products Corporation 100 East Broadway, Box B St. Paul Park, Minn. 55071 Phone (612) 459-6065
Sampler Intake:	Parabolic port in a 3/4" I.D. rigid tube.
Gathering Method:	Mechanical; sampling tube is rotated down into the flow where it fills through the port by gravity; an electric motor rotates the tube up and the sample flows by gravity into the container.
Sample Lift:	Telescoping sampling tubes may be adjusted to reach down to 21 inches from the bottom of sampler.
Line Size:	3/4" I.D.
Sample Flow Rate:	Varies with tube angle.
Sample Capacity:	Varied aliquot sizes of 10, 20 or 30 ml are composited in a single 1-gallon container.
Controls:	Sampling cycle may be triggered at preset time intervals from built-in electrical timer or on signal from external flow meter.
Power Source:	110V ac standard; battery optional.
Sample Refrigerator:	Has ice cavity for cooling.
Construction Materials:	Aluminum outer case with rigid insulation.
Basic Dimensions:	13 5/16"W x 12 5/16"D x 13"H plus clearance for oscillating sampling tube which varies depending upon telescoping adjustment. Portable.
Base Price:	$325 electric; $495 with battery.

Sonford Model HG-4 Evaluation

1. Does not appear capable of sampling a particle large enough to clog it; could be affected by rags or paper; no pump to clog.

2. Sampling tube presents a flow obstruction during sampling period only.

3. Low sampling velocities make representativeness of samples questionable at high flow rates. Does not appear tolerant of variable depth flows.

4. Unless mounted so that sampling tube oscillates in flow direction, large solids could cause damage. Appears susceptible to fouling by stringy materials which could wrap around sampling tube.

5. No provision for automatic staring. No self cleaning features.

6. Collects fixed size samples at either preset time intervals or on signal from external flow meter and composits them in a single container.

7. Appears unsuitable for collection of samples of either floatable materials or coarser bottom solids.

8. Provision for ice cooling affords some sample protection for a limited time. Limited lift may require placing sampler in a vulnerable location. Cross contamination appears very likely.

9. Unit has a small case but requires clearance for oscillating sampling tube. Case has unsealed opening for movement of same.

10. Unit cannot tolerate submersion.

11. No standard provision for heating case. Ice buildup in sampling tube appears a real possibility.

12. Limited lift and restrictions on liquid level variations severely limit range of operating head conditions.

Designation:	TMI FLUID STREAM SAMPLER
Manufacturer:	Testing Machines, Inc. 400 Bayview Avenue Amityville, New York 11701 Phone (516) 842-5400
Sample Intake:	Stainless steel hollow cylindrical body with a 1" inlet and mounted submerged in the stream either on four legs mounted to a bottom plate or suspended from above if in a weir or flume.
Gathering Method:	Forced flow due to pneumatic ejection.
Sample Lift:	Over 25 feet; depends upon air pressure.
Line Size:	1/2" O.D.
Sample Flow Rate:	Depends upon air pressure and lift.
Sample Capacity:	Aliquots of approximately 1 pint are composited in a suitable container provided by user.
Controls:	User must provide air pressure regulator if plant air supply is not regulated; sampling interval timer is adjustable to allow from 1 minute to 1 month to elapse between aliquots; manual on-off switch.
Power Source:	Compressed air supply of at least 20 psi, 100 psi maximum; 110V ac.
Sample Refrigerator:	None.
Construction Materials:	Stainless steel and plastic.
Basic Dimensions:	Largest element will be user supplied sample container; sampling intake 4"W x 9"D x 8"H; timing controller 12"W x 7"D x 15"H.
Base Price:	$660.

General Comments: Sampler developed by International Paper Company for use in the paper industry for checking the loss of useable fiber in effluent, taking consistency samples, etc. Sampler has performed well in flows to 1800 gpm and consistencies to 3.5 percent.

TMI Fluid Stream Sampler Evaluation

1. Sampler should be free from clogging.

2. Sampler intake offers rigid obstruction to flow.

3. Sampling chamber will fill immediately following end of previous sample. Circulation through chamber would appear to be limited, resulting in a sample not necessarily representative of conditions in the sewer at the time of next triggering signal.

4. Movement of small solids should not affect operation; large objects could damage (or even physically destroy) the in-water portion unless special protection is provided by user.

5. No automatic starter; no self-cleaning features.

6. Collects fixed size spot samples and composits them in a suitable container; a 3-minute cycle interval will deliver approximately 60 gallons in 24 hours.

7. Unsuitable for collection of either floatables or coarser bottom solids without special intake designed by user.

8. Sample container provided by user.

9. Not designed for manhole operation.

10. Cannot withstand total immersion.

11. Unit should be capable of operation in freezing ambients.

12. Upper lift limit determined by air supply pressure.

Designation: TMI MARK 3B MODEL SAMPLER

Manufacturer: Testing Machines, Inc.
400 Bayview Avenue
Amityville, New York 11701
Phone (516) 842-5400

Sampler Intake: Twelve 1/4" I.D. vinyl sampling lines are connected to individual ports in a stainless steel sampling head (approx. 4" dia) fitted with a stainless steel filter having approximately 930 1/8" diameter holes.

Gathering Method: Suction lift from vacuum in evacuated sample bottles.

Sample Lift: Sample size reduced as lift increases; 8 to 10 feet appears practical upper limit with 20-ounce bottles.

Line Size: 1/4" I.D.

Sample Flow Rate: Varies with filling time, atmospheric pressure, bottle vacuum, sample lift, etc.

Sample Capacity: Twelve 20-ounce "Medicine Flat" glass bottles are provided. Sample sizes up to 400 ml can be obtained depending upon lift, bottle vacuum and atmospheric pressure; 300 ml is typical.

Controls: A spring driven clock rotates an arm which trips line switches at a predetermined time interval triggering sample collection. Sampling intervals of 1/2 to 8 hours are available.

Power Source: Spring driven clock.

Sample Refrigerator: None.

Construction Materials: PVC coated, light alloy case with; glass bottles with rubber stoppers and rubber lines through switch plate, plastic connectors and vinyl lines to stainless steel sampling head.

Basic Dimensions: 14 1/2" diameter x 26"H; empty weight is 32 pounds; portable.

Base Price: $595 including vacuum pump. Mark 4B model has 24 bottles at $685 for 20-ounce size and $695 for 1 liter size.

General Comments: This unit was originally developed by the Water Pollution Research Laboratory in England and is manufactured by North Hants Engineering Co. Ltd. under license from the National Research Development Corporation.

TMI Mark 3B Model Sampler Evaluation

1. Sampling head is vulnerable to blockage of a number of sampling ports at one time by paper, rags, plastic, etc. Sampling train is an unobstructed 1/4" passageway which will pass small solids. No pump to clog.
2. Sampling head and shroud are simply dangeled in the flow stream to be sampled. No rigid obstruction.
3. Low sampling velocities make representativeness of samples questionable at high flow rates. Vinyl sampling tubes are exposed to flow.
4. Sampling head would appear to be vulnerable to clogging if in bed load. Stainless steel filter offers some protection against movement of solids in flow stream.
5. No automatic starter; clocks allow setting a time delay before sampling commences. No self cleaning features. Proper cleaning of all 24 sampling lines would be difficult and time consuming in the field.
6. Collects discrete samples at preset times from a fixed point intake only.
7. Appears unsuitable for collection of samples of either floatable materials or coarser bottom solids.

8. No sample refrigeration. Limited lift may require placing sampler case in a vulnerable location. Use of individual sampling lines eliminates cross contamination possibility.

9. Unit will pass through a 15" diameter circle. Case has base opening where sampling line bridle emerges.

10. Case will fill with fluid if submerged. Spring clock and drive mechanism then becomes vulnerable, especially if fluid contains solids.

11. No standard provision for heating case. Freezing of sampling lines appears a distinct possibility.

12. Practical upper lift limit of 8 to 10 feet poses restrictions on operating head conditions.

SECTION VII

REVIEW OF CUSTOM DESIGNED SAMPLERS

INTRODUCTION

As was noted in section VI, it has been the practice of many project engineers to custom design one-of-a-kind samplers for use in their projects due to a lack of availability of suitable commercial equipment. In this section several examples of such equipment are reviewed. Inasmuch as there is no dearth of examples, it was necessary to be rather selective in order to keep the overall size of this report within manageable bounds. Several practical considerations also favor less than 100 percent coverage. For example, no attempt has been made to dig back into history in order to examine older concepts and notions. It is felt that any good features in older designs, having proved themselves to be effective, would be incorporated in present day equipment. Furthermore, the major emphasis has been placed in recent EPA project experience.

DESCRIPTIVE FORMS AND EVALUATIONS

The same description and evaluation formats that were used for reviewing the commercially available samplers in section VI are used here with one exception. For these custom designed one-of-a-kind samplers, prices in terms of today's dollars are generally not available and, furthermore, the inevitable engineering changes that one would introduce in building equipment following a prototype would have cost impacts that are not easily assessed.

The samplers have been given names to correspond with either the developer or the project location. The descriptive forms and evaluations presented on the following pages are arranged roughly in chronological order of development, and an index is provided on page x.

Designation:	AVCO INCLINED SEQUENTIAL SAMPLER
Project Location:	Tulsa, Oklahoma
EPA Report No.:	11034 FKL 07/70
Sampler Intake:	Inlet tube passes through an aluminum tube which is hinged at the top of the storm drainage structure and has a polyethylene float at the other end where the inlet tube terminates with a sampling probe.
Gathering Method:	Suction lift from peristaltic pump.
Sample Lift:	Not stated, but probably 15 to 20 feet maximum.
Line Size:	1/8" I.D.
Sample Flow Rate:	Not stated, but must be fairly low for inclined sequential filling scheme to be meaningful.
Sample Capacity:	Unit sequentially fills a 60 ml sample bottle, then a 2,000 ml sample bottle, and repeats this 6 times, i.e., until it has filled six 60-ml and six 2,000-ml bottles; then it collects a composite sample in a 5 gallon overflow bottle
Controls:	A limit switch on the hinged float arm starts the pump when the flow level exceeds a preset value. When the flow level subsides the pump is shut off.
Power Source:	12V dc marine battery.
Sample Refrigerator:	None.
Construction Materials:	Polypropylene pick-up tube, tygon and polyethylene connecting tubes, polyethylene bottles; aluminum frame, wood case.

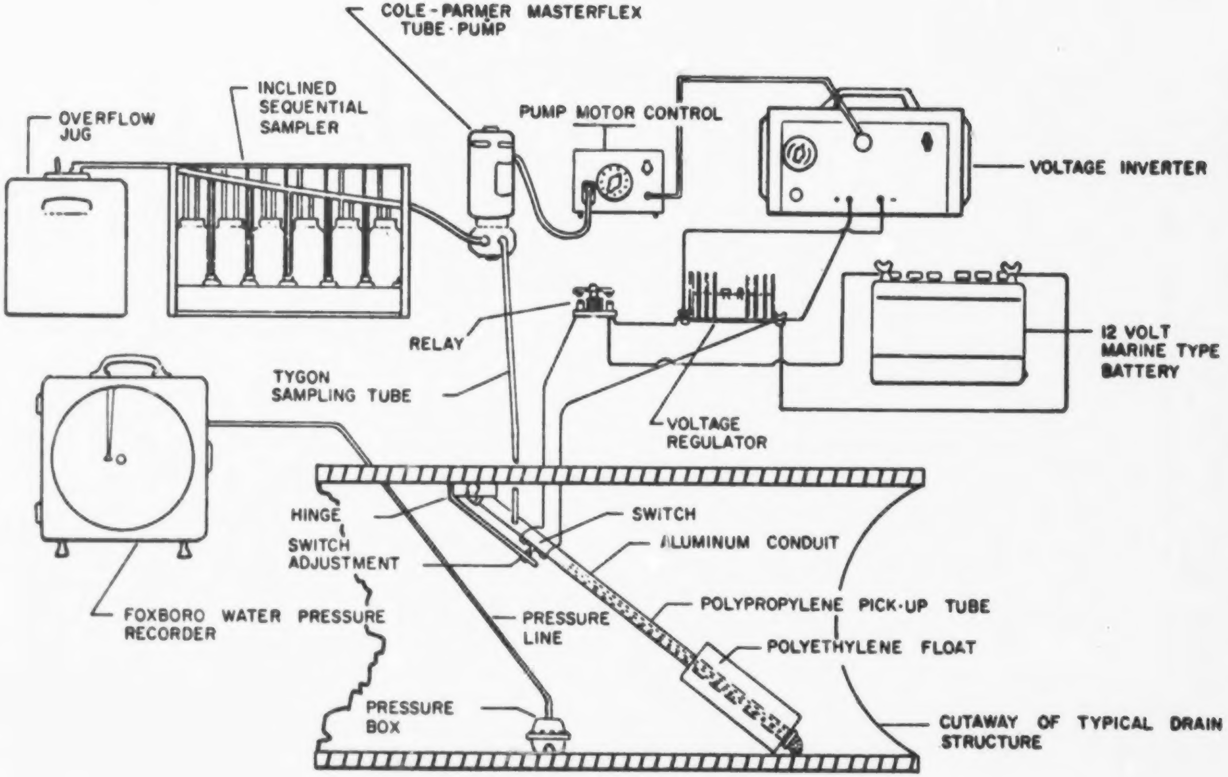
COLE-PARMER MASTERFLEX TUBE·PUMP
INCLINED SEQUENTIAL SAMPLER
OVERFLOW JUG
PUMP MOTOR CONTROL
VOLTAGE INVERTER
RELAY
TYGON SAMPLING TUBE
VOLTAGE REGULATOR
12 VOLT MARINE TYPE BATTERY
HINGE
SWITCH ADJUSTMENT
SWITCH
ALUMINUM CONDUIT
FOXBORO WATER PRESSURE RECORDER
PRESSURE LINE
POLYPROPYLENE PICK·UP TUBE
POLYETHYLENE FLOAT
PRESSURE BOX
CUTAWAY OF TYPICAL DRAIN STRUCTURE

Figure 13. AVCO Inclined Sequential Sampler

Taken from EPA Report No. 11034 FKL 07/70.

Basic Dimensions: Bottle rack is 28"W x 6"D x 16"H. Both semi-stationary and portable configurations were assembled.

General Comments: A pressure box in the flow and connected to a Foxboro water pressure recorder was used. Components included a Cole-Parmer Masterflex tube pump, Model No. 7015 and a Terado power inverter (Allied No. 21f4499). The sequential filling of the sample bottles is simply performed by arranging their inlet tubes in order along an inclined manifold.

AVCO Inclined Sequential Sampler Evaluation

1. Clogging is likely in samples with high solids content due to numerous 1/8" obstructions in sampling train unless a filter is used; sampling probe points downstream and is near the surface due to float, but could possibly be affected by paper, plastic, etc.

2. Float and arm will be completely submerged in a full pipe flow situation and present an obstruction to flow.

3. Unit should operate over full range of flows, but low sample flow rate makes representativeness questionable for high stream flows.

4. Movement of solids in the flow stream could hamper operation.

5. Unit starts automatically when flow level rises above a preset height; no self cleaning features.

6. Sequentially fills sample bottles from output of a continuously running pump. Flow rate provides the only timing function. Samples will be representative of the near-surface water at best.

7. Unit may collect some floatables but is totally unsuited for collecting coarser bottom solids.

8. No refrigeration. Some cross-contamination is guaranteed due to filling stem arrangement, especially for 60-ml bottles.

9. Unit does not appear ideally suited for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit is unsuitable for use in freezing ambients.

12. A 15 to 20 foot lift limit puts slight restriction on operating head conditions.

Designation:	SPRINGFIELD RETENTION BASIN SAMPLER
Project Location:	Springfield, Ill.
EPA Report No.:	11023 - - - 08/70.
Sampler Intake:	End of 920 foot long influent line suspended 6" below water surface from a float.
Gathering Method:	Suction lift from a screw rotor pump.
Sample Lift:	Less than 14 feet required in this application.
Line Size:	1 1/2" diameter lagoon influent sample intake line, 4" diameter lagoon effluent sample intake line.
Sample Flow Rate:	Approximately 240 gph.
Sample Capacity:	Intake lines discharged into 16 gallon sampling tanks. A constant volume aliquot was obtained each 30 minutes and composited in a 5-gallon container.
Controls:	A Lakeside Trebler scoop sampler was used to remove aliquots from sampling tanks. See discussion of that sampler for details.
Power Source:	115V ac
Sample Refrigerator:	Automatic thermostatically controlled refrigerators were used to house sample containers.
Construction Materials:	ABS plastic intake lines, PVC sample bottles, sampling tank appears to be metal, pump materials not given.
Basic Dimensions:	Components are distributed within a general purpose equipment building; fixed installation.

General Comments:	Moyno pumps operating on a continuous basis were used to provide sample flow through a 16 gallon sampling tank. Two samplers were constructed, one for the lagoon influent and one for the effluent. Since the Lakeside Trebler sampler is evaluated elsewhere, no further evaluation of this installation will be made.

Designation: MILK RIVER SAMPLER

Project Location: Grosse Point Woods, Mich.

EPA Report No.: 11023 FBD 09/70

Sampler Intake: Overflow system influent sampler intake was simply inlet of submersible pump suspended beyond the bar screens within the transition structure between sewer and wet well. Effluent sampler intake was four 1-inch vertical suction lines spaced evenly along the 210 foot long effluent weir which drew their samples from points between the skimming baffle and weir at a depth above the bottom of the baffle and just below the outlet weir.

Gathering Method: Forced flow from submerged pump for influent sampler; suction lift from centrifugal pump for effluent sampler.

Sample Lift: Not stated.

Line Size: Except for 1" diameter inlet lines leading to effluent sampler header, all sampling lines were 2" diameter.

Sample Flow Rate: Not stated.

Sample Capacity: Samplers collect adjustable grab samples from the continuously flowing 2-inch pipe streams, composite them for variable periods and hold them in a refrigerated compartment for periods up to about 3 hours.

Controls: The size of each grab sample is controlled externally. Otherwise, the sampling program is controlled by a continuous punched paper tape program which varies the collection time of each composite, the number of grab samples in each composite, and each of the variables from one sampling time to another.

Power Source: 115V ac

Sample Refrigerator: Automatic thermostatically controlled refrigerated sample compartments.

Construction Materials: Metal, plastic, and wood were used in construction; no details were given.

Basic Dimensions: Indoor portion of sampler is large, perhaps 6'W x 3'D x 5'H or so; fixed installation.

General Comments: This unit apparently functioned fairly well on the project for which it was designed. Since it is a custom designed, fixed installation unit no complete evaluation will be made.

Designation:	ENVIROGENICS BULK SAMPLER
Project Location:	San Francisco, California
EPA Report No.:	11024 FKJ 10/70
Sampler Intake:	A metal container resembling an inverted roadside mail box approximately 14 1/2" long and 14" deep with a 6" radius; hinged covers at each end are mechanically connected to function integrally upon activation of an air cylinder.
Gathering Method:	Mechanical; the sampler intake assembly is designed to fit a special support structure which must be installed in the manhole chosen for sampling. It is lowered to the bottom of the invert whereupon the covers are closed thereby trapping a plug of the combined sewage inside the sampler. The filled sampler was then raised by winch to the surface.
Sample Lift:	Depth of manhole in question. No real limit.
Line Size:	Not applicable.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Roughly 9 gallons maximum.
Controls:	Manually operated.
Power Source:	Compressed air.
Sample Refrigerator:	None.
Construction Materials:	Aluminum.
Basic Dimensions:	14 1/2"W x 12"D x 14"H plus brackets and supporting structure, etc.

Envirogenics Bulk Sampler Evaluation

1. Unit should be free from clogging except for possibility of large debris interfering with flap closure.

2. Unit will completely obstruct flow the instant the covers are closed, but will clear as raised.

3. Since sampler must be designed for the specific manhole invert size in which it is to be used, it is suitable for all flow conditions.

4. Movement of solids in flow will not affect operation except where a significant bed load would prevent sampler from coming to rest on the invert.

5. Unit is manually operated. Cleaning is accomplished by the running sewage.

6. Sampler removes a "plug" of the sewage flow covering the entire flow cross-section.

7. Unit should sample both floatables and coarser bottom solids.

8. Unit is not suitable for sample storage.

9. Unit is designed for manhole operation, but also requires clear area above manhole for hoist and personnel.

10. Unit operates totally immersed; if manhole is surcharging sample might be less representative.

11. Unit should operate in freezing ambients.

12. Unit is indifferent to operating head conditions.

Designation:	ROHRER AUTOMATIC SAMPLER MODEL I
Project Location:	Sandusky, Ohio
EPA Report No.:	11022 ECV 09/71
Sampler Intake:	Not clearly stated but presumably the end of the suction line mounted in the overflow conduit just beyond the leaping weir.
Gathering Method:	Suction lift from diaphram pump.
Sample Lift:	Not stated but probably good for at least 20 feet.
Line Size:	Smallest line would appear to be the one connecting the diverter head to the sample container, but size is not given.
Sample Flow Rate:	Not stated but presumably rather large.
Sample Capacity:	Unit collects twenty-four 1-pint discrete samples plus a flow proportional composite of up to 5-gallons.
Controls:	Sampling is automatically started when the leaping weir diverts flow into the overflow flume. Discrete samples were collected every 5 minutes paced by a built-in timer adjustable from 5 to 60 minutes. Constant volume composite aliquots are added for each 10,000 gallons of flow through the overflow flume.
Power Source:	115V ac
Sample Refrigerator:	None
Construction Materials:	Not stated.
Basic Dimensions:	None given but a fixed installation located in a building specially erected for the project.

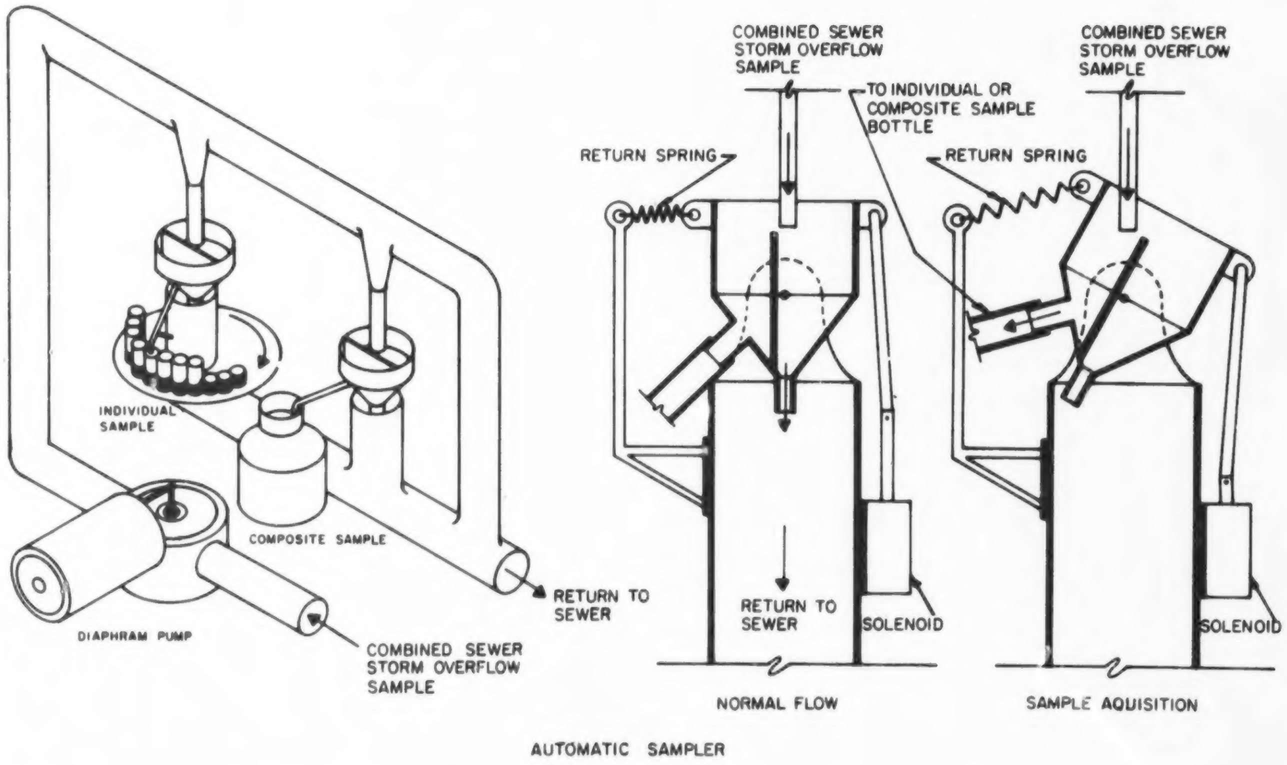
INDIVIDUAL SAMPLE
COMPOSITE SAMPLE
DIAPHRAM PUMP
COMBINED SEWER STORM OVERFLOW SAMPLE
RETURN TO SEWER
COMBINED SEWER STORM OVERFLOW SAMPLE
TO INDIVIDUAL OR COMPOSITE SAMPLE BOTTLE
RETURN SPRING
RETURN TO SEWER
SOLENOID
NORMAL FLOW
COMBINED SEWER STORM OVERFLOW SAMPLE
RETURN SPRING
SOLENOID
SAMPLE AQUISITION
AUTOMATIC SAMPLER

Figure 14. Rohrer Automatic Sampler

Taken from EPA Report No. 11022 ECV 09/71

General Comments:

The pump produces a continuous flow of sewage through the sampling header pipe and back to the sewer. Two taps are provided to allow continuous flow through diversion nozzles for the individual and composite sample collection stations and return to sewer. When it is desired to collect a sample, a solenoid is actuated operating a linkage which mechanically rotates the diversion nozzle causing the flow to enter a chamber connected to the sample bottle rather than the sewer return. A spring assures return of the diversion nozzle to its original position after the sample is taken. The time of solenoid activation governs the size of the sample. The 24 discrete sample bottles are mounted on a turntable which indexes upon each sampling cycle to place an empty bottle under the filling spout.

Rohrer Automatic Sampler Evaluation

1. Should be relatively free from clogging.
2. Unit would not appear to offer any significant obstruction to flow.
3. Unit should be operable over the full range of flow conditions.
4. Movement of solids in the flow should not hamper operations.
5. Automatic operation. Continuous flow serves a self cleaning function.
6. Collects 24 discrete samples at pre-set time intervals and a flow proportional composite.
7. Ability to collect floatables and coarser bottom solids will depend upon details of sampling intake.
8. No refrigeration, but otherwise unit would appear to afford reasonable sample protection.

9. Unit was not designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit would appear capable of operation in freezing ambients.

12. Relatively high lift should allow operation over a fairly wide range of operating head conditions.

Designation: WESTON AUTOMATIC SAMPLER

Project Location: Washington, D.C.

EPA Report No.: 11024 EXF 08/70

Sampler Intake: Details of intake to submersible sewage pump and of sampling head to vacuum-charged sampler not stated.

Gathering Method: Forced flow to a retention tank by a sewage pump anchored to the sewer floor, thence, by vacuum, from the retention tank to sample bottles.

Sample Lift: Not stated.

Line Size: Not stated.

Sample Flow Rate: Not stated.

Sample Capacity: Collects 24 discrete samples.

Controls: Wastewater is pumped continuously to the retention tank. The vacuum tank is triggered by the increased back-pressure of a bubbler line resulting from the increased depth of sewer flow. The discrete interval is adjusted by an electric timer to a minimum period of 5 minutes.

Power Source: 115V ac

Sample Refrigerator: Sample bottles, sampling lines, and control switches installed in a refrigerated enclosure.

Construction Materials: Not stated.

Basic Dimensions: The wastewater retention tank, the refrigerated sampler, and the piping are all housed in a 7' x 5'3" x 6'6" metal shed.

FIGURE D-1
MONITORING EQUIPMENT

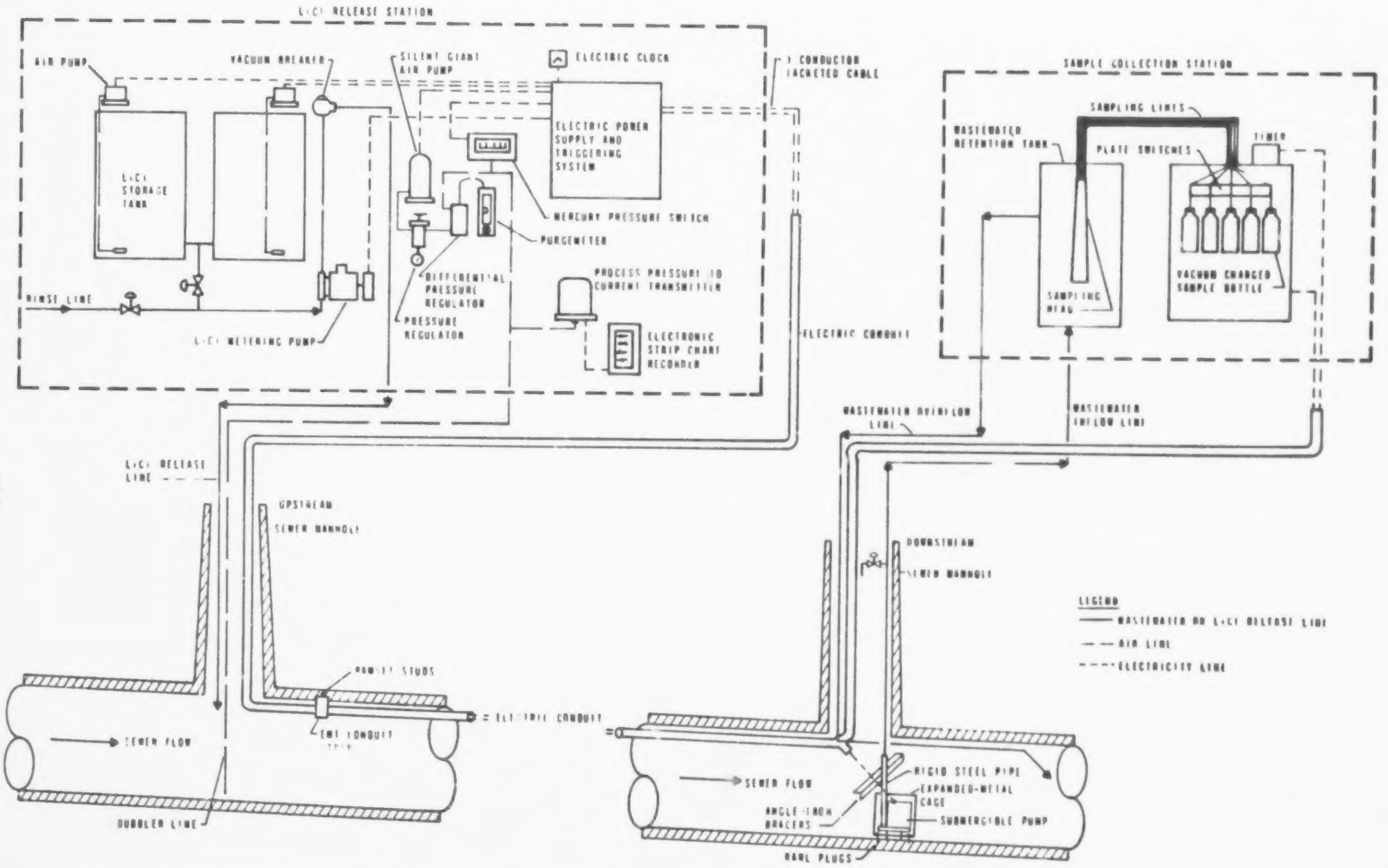
LiCl RELEASE STATION
AIR PUMP
VACUUM BREAKER
SILENT GIANT AIR PUMP
ELECTRIC CLOCK
LiCl STORAGE TANK
ELECTRIC POWER SUPPLY AND TRIGGERING SYSTEM
MERCURY PRESSURE SWITCH
PURGEMETER
DIFFERENTIAL PRESSURE REGULATOR
PRESSURE REGULATOR
PROCESS PRESSURE TO CURRENT TRANSMITTER
ELECTRONIC STRIP CHART RECORDER
RINSE LINE
LiCl METERING PUMP
3 CONDUCTOR JACKETED CABLE
ELECTRIC CONDUIT
SAMPLE COLLECTION STATION
SAMPLING LINES
WASTEWATER RETENTION TANK
PLATE SWITCHES
TIMER
SAMPLING HEAD
VACUUM CHARGED SAMPLE BOTTLE
WASTEWATER OVERFLOW LINE
WASTEWATER INFLOW LINE
LiCl RELEASE LINE
UPSTREAM SEWER MANHOLE
RAMSET STUDS
ELECTRIC CONDUIT
EMT CONDUIT
SEWER FLOW
BUBBLER LINE
DOWNSTREAM SEWER MANHOLE
LEGEND
WASTEWATER OR LiCl RELEASE LINE
AIR LINE
ELECTRICITY LINE
SEWER FLOW
RIGID STEEL PIPE
EXPANDED-METAL CAGE
SUBMERSIBLE PUMP
ANGLE-IRON BRACERS
RAWL PLUGS
D-1

Figure 15. Weston Automatic Sampler

Taken from EPA Report No. 11024 EXF 08120.

General Comments: A submersible, heavy-duty manually-controlled sewage pump delivers wastewater continuously to a retention tank having a normal retention time of less than 1 minute. The pump is anchored to the sewer bottom in a metal cage.

During a storm, an increase of water depth in the sewer applies back pressure to an air-bubbling system, thus activating a mercury switch and triggering the system which collects samples from the retention tank. The 24 sample bottles are vacuum charged prior to the storm by use of a portable vacuum pump. The bottles are in a fixed position in the refrigerated enclosure, and each sample is drawn into its bottle by vacuum when a control switch is released by a tripper arm operated in conjunction with a timer.

Weston Automatic Sampler Evaluation

1. The submersible pump anchored to the bottom of the sewer is often clogged by solid wastes such as cans, rags, wire, wood chips, tree stems, gravel, sand, etc.

2. The submersible pump with its metal cage and angle iron braces offers a significant obstruction to flow.

3. Pump stoppages have occurred during low-intensity storms, probably because of insufficient water depth in the sewer.

4. Movement of heavy solids has caused severe damage to the equipment, to the extent that pumps have washed away.

5. Automatic operation of sampler above retention tank. Continuous flow from pump to retention tank assists in self cleaning.

6. Collects 24 discrete samples at preset time intervals. Synchronized recorded flow data permit flow proportional compositing. Samples are collected from a single elevation in the sewer.

7. Ability of unit to collect floatables or coarser bottom solids will depend upon elevation of pump intake.

8. Refrigerated sample container protects samples from damage and deterioration. Continuous flow from sewer to retention tank will help minimize cross-contamination. Sampling head and lines may be susceptible to precontamination.

9. Unit was not designed for manhole operation.

10. Unit cannot operate under a condition of total immersion.

11. Not suitable for operation under freezing ambient conditions. Could be made to operate during freezing weather by heating the metal shed housing the unit.

12. Relatively high discharge pressure would allow operation over a wide range of operating head conditions.

Designation:	PAVIA-BYRNE AUTOMATIC SAMPLER
Project Location:	New Orleans (Lake Pontchartrain), Louisiana
EPA Project No.:	11020 FAS. Final report should be available about June 1973.
Sampler Intake:	Saran wrapped, galvanized sheet metal air diffuser about 2 1/2' long, placed about 8" below the water surface. Polyethylene tubing from intake to sampler.
Gathering Method:	Positive displacement, screw type, Moyno or Aberdenffer pump operated with a 3/4 HP motor.
Sample Lift:	Maximum suction lift about 20 feet.
Line Size:	Minimum 3/4" line from canal to sampler. Intake pipe to sampler manifold 3/4". Manifold to each row of sampler bottles, 1/2". Line from solenoid valve to sampler, 1/4".
Sample Flow Rate:	2 to 3 gallons per minute.
Sample Capacity:	Unit collects 36 discrete samples in bottles of about 40 ounce capacity each.
Controls:	Sampler operation initiated with manually operated switch. Filling of sample bottles controlled by a motor driven timer, through relays, to a solenoid valve at each sample bottle. Time interval between sample collections not stated.
Power Source:	Sample pump operates through a 220 volt, 60 cycle, external power source. Electrical control equipment is on a 120 volt, 60 cycle, power source.

Sample Refrigerator:	Sample bottles, solenoid valves to each bottle, and sampler manifold, are installed in a Shaefer Cooler Model MC-1600, with cooling units built in its walls.
Construction Materials:	Sampler piping and fittings are of PVC. Grating and supports within the cooler are aluminum.
Basic Dimensions:	Outside dimensions of cooler in which sampler is installed are about 31" x 61" x 35". All equipment is installed in a 6' x 8' shed.
General Comments:	The pump produces a continuous flow of sewage to the sampler. When the sampler has been placed in operation, individual solenoid valves from the sampler manifold are opened one at a time to the 36 sample bottles by an electrically operated timer. A combination standpipe and overflow line is used to maintain pressure on the solenoid valves.

Pavia-Byrne Automatic Sampler Evaluation

1. Most clogging would be at the air diffuser inlet. Its extent would depend on the size and shape of openings in the diffuser.

2. The air diffuser intake would present some obstruction of flow, depending on where it is placed in the sewer. This would not be significant in the very large canal where the existing samplers have been installed.

3. Probably would operate at the full range of flow conditions, except at very low stages, when the air diffuser may not provide satisfactory inlet conditions.

4. Damage to the air diffuser intake may occur in storm or combined sewers of high flow velocity and heavy debris load.

5. Operation is automatic after initial startup at the beginning of a storm. Continuous flow promotes self cleaning.

6. Representativeness of sample depends on placement and configuration of the air diffuser intake. Discrete samples of uniform size collected at constant time intervals. Flow proportional compositing not possible unless time-synchronized with a recording flow meter.

7. Does not collect floatable material because the intake is set below the water surface.

8. Cooled sample container protects samples from damage and deterioration. Continuous flow from sewer to sampler minimizes precontamination.

9. Unit was not designed for manhole operation.

10. Not designed to operate under total immersion or flooding.

11. Continuous flow and insulated cooler would help permit continued operation under ambient freezing.

12. Relatively high lift would allow operation over a fairly wide range of operating head conditions.

Designation: REX CHAINBELT, INC. AUTOMATIC SAMPLER

Project Location: Kenosha, Wisconsin

EPA Project No.: 11023 EKC. Final report should be available about July 1973.

Sampler Intake: Pipe drilled with 1/4" to 3/8" holes.

Gathering Method: Uses a "Hushpuppy" positive pressure pump. Cost of pump about $30. Operates only during a 2-3 minute purging period and during actual filling of sample bottle.

Sample Lift: Suction lift about 15 feet.

Line Size: One-half inch Tygon tubing and garden hose.

Sample Flow Rate: Approximately 3 gpm.

Sample Capacity: Unit collects 18 discrete samples in bottles of 1-liter capacity.

Controls: Sampler operation started by manually operated control. Thereafter, flow to sample bottles is regulated by an electric timer and solenoid valve. Time interval between filling of bottles can be adjusted between 3 minutes and 1 hour.

Power Source: Not stated.

Sample Refrigerator: None provided.

Construction Materials: Sampling lines are composed of Tygon tubing and garden hose; pump is plastic and Buna N.

Basic Dimensions: Not stated.

General Comments: After manual starting, the pump runs for 2 to 3 minutes to purge the sampler lines. The pump then operates only while each sample bottle is filled through a revolving solenoid valve regulated by an electric timer. Apparently, the pump operation is stopped automatically after 18 sample bottles have been filled.

Rex Chainbelt Automatic Sampler Evaluation

1. Experience has been only in sewage which has been comminuted and passed through a grit chamber, but unit should be fairly free from clogging.

2. The pipe sampler intake would present some obstruction of flow, the extent of obstruction depending on the method used for maintaining the position of the pipe in the flow.

3. Does not collect enough samples at short time intervals to include the entire storm period at many locations.

4. Operation impediment by the movement of solids will depend on the method used for installation of the sampler intake pipe.

5. Operation is automatic after initial startup at the beginning of a storm. Self cleaning limited to initial purging of lines.

6. Representativeness of sample depends on placement, and specifications of the intake pipe. Discrete samples of uniform size are collected at constant time intervals. Flow proportional compositing not possible unless time-synchronized with a recording flow meter.

7. Unit could provide some capability for floatables and bottom solids depending upon positioning and length of sampler pipe.

8. No provision for refrigeration of samples provided. Purging of lines prior to sample collection serves to reduce precontamination; cross-contamination will probably occur.

9. Unit was not designed for manhole operation.

10. Not designed to operate under total immersion or flooding.

11. Unit not designed to operate under freezing conditions.

12. Relatively high lift would allow operation over a fairly wide range of operating head conditions.

Designation: COLSTON AUTOMATIC SAMPLER

Project Location: Durham, North Carolina

EPA Project No.: 11030 HJP. Final report should be available about July 1973.

Sampler Intake: Direct intake to sump pump set on piling at stream bed. Intake from sampling flume is a standard Serco Model NW-3 sampling head.

Gathering Method: Water pumped from stream to sampling flume with an Ento-Cornell sump pump, Model No. 150A. Pump is placed inside a 2' x 1'6" metal box, all within a woven wire frame. A standard Serco Model NW-3 vacuum sampler gathers samples from the 3' x 10 1/2" x 3/4" Plexiglas flume.

Sample Lift: About 11 feet from the pump to the sampling flume. No lift from the flume to the Serco sampler.

Line Size: Line from pump to flume is 1 1/2" fire hose. Serco sampler lines are 1/4" I.D.

Sample Flow Rate: Flow rate from pump to flume is about 50 gpm. Flow rate from flume to Serco sampler is variable.

Sample Capacity: Twenty-four 500-ml bottles are provided in the Serco sampler. Actual sample sizes are about 400 ml.

Controls: Operation of pump starts and stops when float in an offstream stilling well reaches specified stages. For Serco Model NW-3 sampler controls, see page 118.

Power Source: Pump operates on 110V ac. Serco sampler is powered with a spring driven clock.

Sample Refrigerator: None provided.

Construction Materials:	Sampling train composed of fire hose, Plexiglas flume, stainless steel sampling head, vinyl lines, and glass bottles with rubber stoppers.
Basic Dimensions:	Not a concentrated unit. Serco sampler; 15 1/2"W x 15 1/2"D x 26 3/4"H.

Colston Automatic Sampler Evaluation

1. Because of large diameter hose from the pump to the sampling flume, and continuous flow during the period of operation, clogging is infrequent. Experience has been in an urban stream which has the characteristics of a storm sewer.
2. The pump and covering, as placed on the stream bed, would create a significant obstruction to flow, particularly in a sewer of ordinary dimensions.
3. May not operate during very low flows, depending upon height of pump inlet above stream bed.
4. Heavy bed loads could render the pump inoperable.
5. Pump starts and stops automatically in accordance with specified water stages. Continuous flow to sampling flume provides self cleaning, but the Serco sampler has no self cleaning features.
6. Collects discrete samples at preset times from a fixed point intake only. Flow proportional compositing is possible when time is synchronized with recording flow measurement equipment.
7. Unsuitable for collection of samples of floatables or coarser bottom solids.
8. No refrigeration provided. Use of individual sampling lines in the Serco sampler eliminates cross-contamination possibility.
9. Not designed for operation in sewer manholes or other confined spaces.
10. Not operable under conditions of total immersion or flooding.

11. Would not operate under freezing conditions.

12. Sample lift of about eleven feet to the sampling flume, and a potential lift of 8 to 10 feet for the Serco sampler, indicates capability for operation under a fairly wide range of operating head conditions.

Designation:	ROHRER AUTOMATIC SAMPLER MODEL II
Project Location:	To be used in Akron, Ohio
EPA Report No.:	None
Sampler Intake:	Not clearly stated but presumably the end of the 2" I.D. suction line mounted directly in the flow stream to be sampled.
Gathering Method:	Suction lift from diaphram pump.
Sample Lift:	Not stated but probably good for at least 20 feet.
Line Size:	3/4" I.D.
Sample Flow Rate:	Depends upon lift; could exceed 20 gpm.
Sample Capacity:	Unit collects twenty-four 1/2-gallon discrete samples plus a 5-gallon composite.
Controls:	Has a provision for automatic starting. Discrete samples and composite aliquots can be collected every 5 minutes paced by a built-in timer adjustable from 5 to 60 minutes. Switches automatically stop diversion to composite bottle when it is full and shut sampler off when last discrete bottle has been filled.
Power Source:	115V ac
Sample Refrigerator:	None
Construction Materials:	Tygon and PVC tubing; aluminum diverter, nozzle, etc.; "Nalgene" sample bottles; aluminum frame.
Basic Dimensions:	54"W x 30"D x 59"H including mounting dolly. Can be wheeled about, but appears too heavy to lift without assistance.

General Comments: The pump produces a continuous flow of sewage through the sampler diverter and back to the sewer. Two solenoids are provided to allow diversion of flow to either the discrete or composite sample container for a preset time period. They tip a nozzle inside a diversion chamber and thus direct the flow as commanded by the timing cams. The nozzle is spring loaded to return to its null position which directs flow back to the sewer. A rotating nozzle is indexed over one of 24 funnels, each connected by a piece of 3/4" I.D. tygon tubing to one of the wide mouth discrete sample bottles which are in a rectangular array.

Rohrer Automatic Sampler Model II Evaluation

1. Should be relatively free from clogging, except perhaps the tubes connecting the distribution funnels to the discrete sample bottles.
2. Unit would not appear to offer any significant obstruction to flow.
3. Units should be operable over the full range of flow conditions.
4. Movement of solids in the flow should not hamper operations, except for possible diaphram wear.
5. Capable of automatic operation. Continuous flow serves a self cleaning function.
6. Collects 24 discrete samples at preset time intervals and a simple composite.
7. Ability to collect floatables and coarser bottom solids will depend upon details of sampling intake.
8. No refrigeration, but otherwise unit would appear to afford reasonable sample protection.
9. Unit was not designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit would appear capable of operation in freezing ambients.

12. Relatively high lift should allow operation over a fairly wide range of operating head conditions.

Designation:	NEAR SEWER SAMPLER
Project Location:	Tested at San Jose Water Pollution Control Plant.
EPA Report No.:	None. Not developed under EPA sponsorship.
Sampler Intake:	Small hole (approximately 1/2" diameter) in the side of a traversing pick-up tube.
Gathering Method:	Mechanical; pick-up tube with piston is lowered and fills through intake near its lower end as it traverses the stream to be sampled. Sample is ejected through a hole near the top of the tube by raising the piston inside the tube.
Sample Lift:	Will depend upon pick-up tube length; 6-8 feet would appear to be a practical maximum.
Line Size:	Smallest line (possibly 1/2") would appear to be the one connecting the sample bottle to the pick-up tube outlet.
Sample Flow Rate:	Not applicable.
Sample Capacity:	Developer simply states that either a composite sample or a number of discrete samples can be provided.
Controls:	An upper piston was added to allow varying the quantity of samples gathered during the stream depth traverse in a controlled way. It is activated by a water surface sensor located on the bottom of the pick-up tube. The water sensor provides the capability (in conjunction with a small memory and logic unit) of gathering flow-proportional samples, at least to the extent that flow is

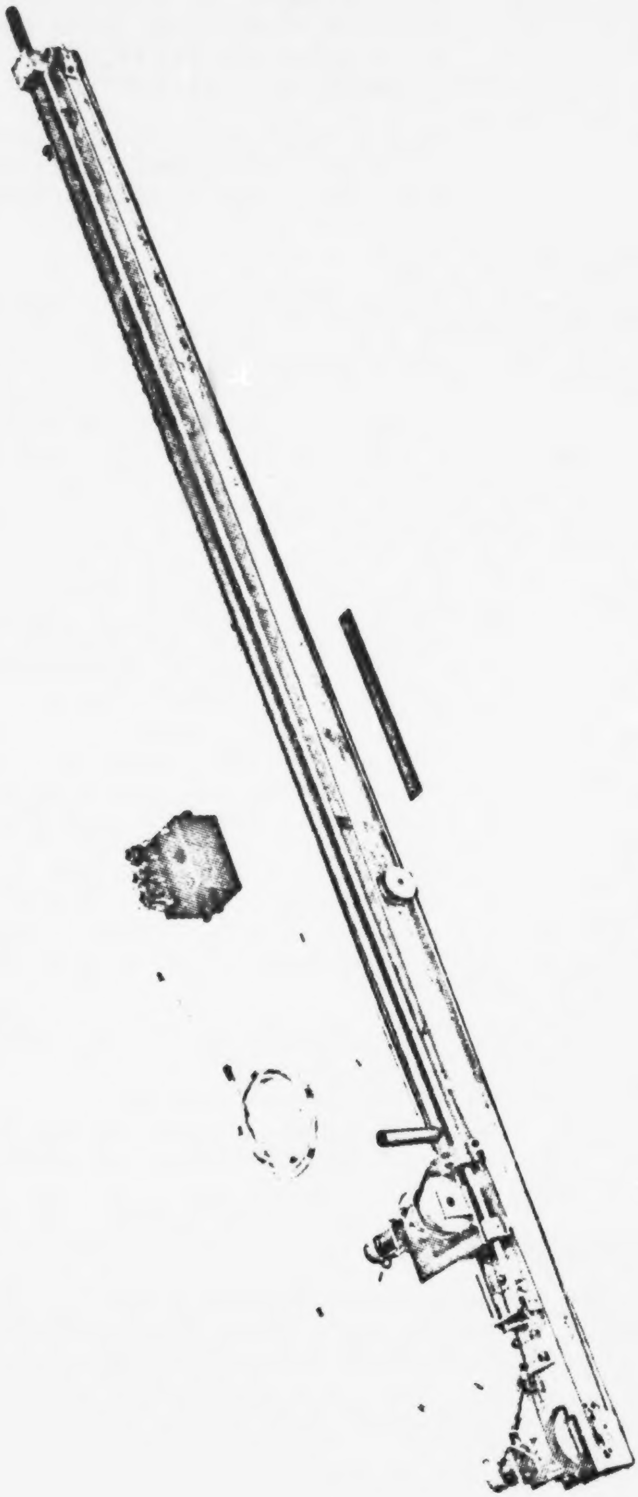

Figure 16. NEAR Sewer Sampler

Photograph courtesy of Nielson Engineering and Research, Inc.

proportional to water depth. Otherwise samples could be paced by a timer or arranged to accept signals from an external flowmeter.

Power Source: Basic unit could be battery powered. External controls could require alternating current.

Sample Refrigerator: None

Construction Materials: Stainless steel and plastic.

Basic Dimensions: Will depend upon length of pick-up tube; say approximately 1'W x 1'D x 8'H plus a sample container rack. Unit must be mounted in manhole or otherwise near the flow stream. Basic unit would appear to weigh 30-40 pounds.

General Comments: Sampler is out of the main flow except when taking a sample. Developer claims sampler can pick-up a representative sample of surface oil film. Both an initial model and an improved prototype have been fabricated and tested to demonstrate the basic concepts involved, but the unit has not been made commercially available as yet. A patent application has been filed on the sampler and its concept. Any requests for further information should be directed to:

S. B. Spangler, Vice President
Nielsen Engineering & Research, Inc.
850 Maude Avenue
Mountain View, California 94040
Telephone (415) 968-9457

NEAR Sewer Sampler Evaluation

1. Pick-up tube might collect debris (rags, paper, etc.) during traverse which could clog inlet port; otherwise should be relatively free from clogging.

2. Pick-up tube offers a rigid obstruction to flow while sample is actually being collected.

3. Unit would appear vulnerable to damage due to Strouhal vibration at high flow rates.

4. Movement of large objects in the flow at the time a sample is being taken could damage or even physically destroy the pick-up tube assembly.

5. Prototype does not have an automatic start feature. No self cleaning. Cross contamination appears very likely.

6. Prototype is amenable to several types of control systems, but none has been demonstrated as yet.

7. Preliminary test results indicate a capability of collecting surface oil films. Unit is unsuitable for collecting coarse bottom solids.

8. Sample container case not designed. Since unit mounts in manhole near flow surface, samples are vulnearable, and refrigeration does not appear reasonable.

9. Unit is designed for manhole operation.

10. Unit cannot withstand total immersion.

11. Unit would appear to have difficulty operating in freezing ambients.

12. Unit has design capability of operating over a fairly wide range of operating head conditions.

Designation: FREEMAN AUTOMATIC SAMPLER

Project Location: Columbia, Maryland

EPA Report No.: None

Sampler Intake: Provided by user.

Gathering Method: External head to provide flow to sampling equipment shed. Fluidic diverters are controlled by solenoid valves by timer signals and divert flow to discrete sample containers, the flow otherwise returning to waste.

Sample Lift: Not applicable.

Line Size: The smallest passage in the sampling train is the 1/4" x 1/4" throat of the diverter.

Sample Flow Rate: 1.5 gpm.

Sample Capacity: Modularized construction allows as many 1 quart discrete sample containers to be used as desired. For this installation, 6 modules were arranged vertically in a single cascade, and two cascades were employed.

Controls: Timer-actuated solenoid valves open and close the diverter control ports causing a sample to be taken at preset time intervals. Volume of sample is adjusted by positioning the vent tube in the sample jar.

Power Source: 110V ac

Sample Refrigerator: None

Construction Materials: PVC pipe, fluidic diverters molded from PVC, sample containers are glass Mason jars, metal and plywood frame.

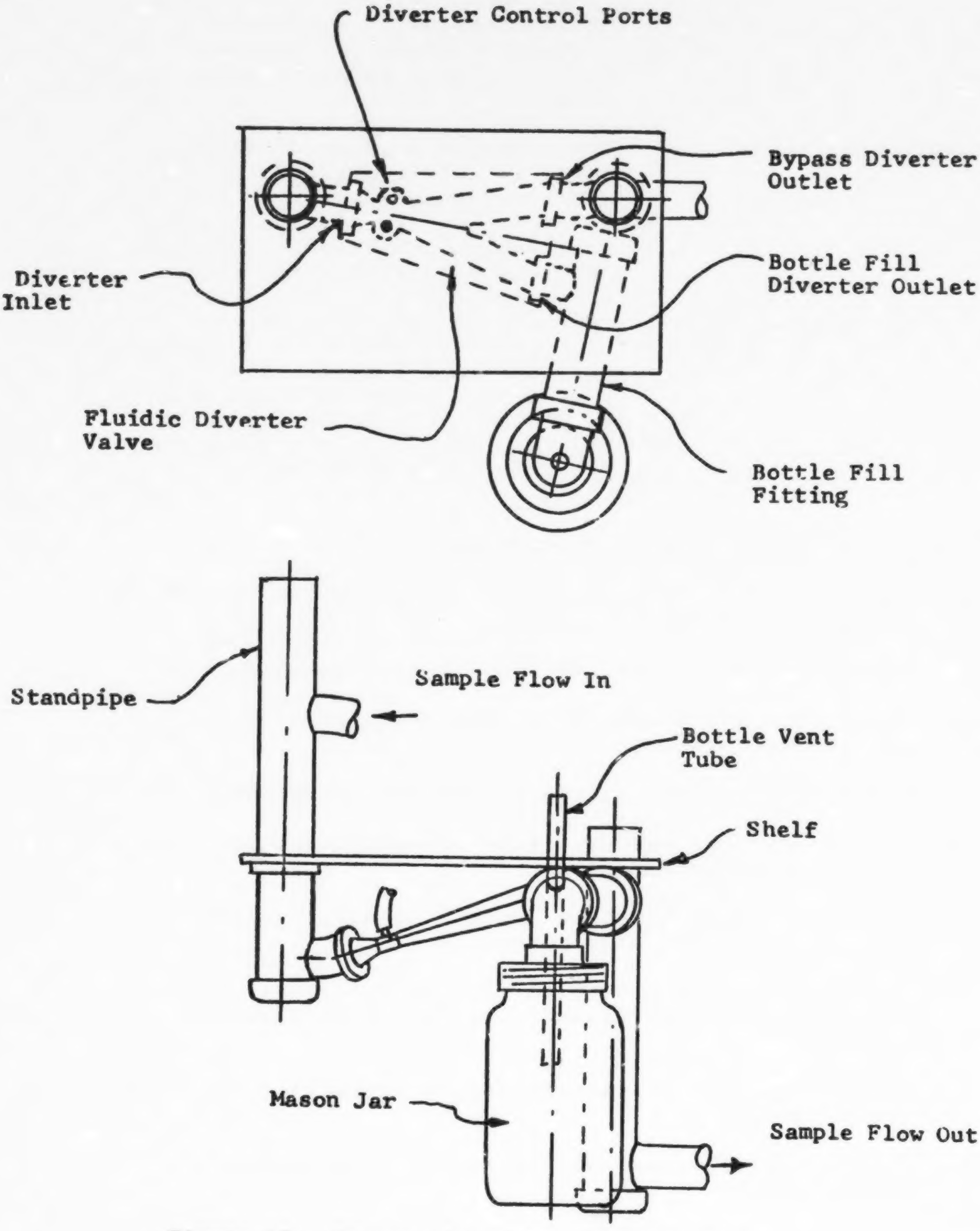
Diverter Control Ports
Bypass Diverter Outlet
Diverter Inlet
Bottle Fill Diverter Outlet
Fluidic Diverter Valve
Bottle Fill Fitting
Standpipe
Sample Flow In
Bottle Vent Tube
Shelf
Mason Jar
Sample Flow Out

Figure 17. Freeman Automatic Sampler Module

Sketch courtesy of Peter A. Freeman Associates, Inc.

Basic Dimensions: Each 6 module cascade appears to be about 1 1/2'W x 1'D x 5'H. Minimum height of a module is 6" head required for diverter operation plus sample bottle height.

General Comments: The complete absence of moving parts in the flow stream is a distinct advantage. With the use of a bias orifice in one control port, only one control line need be blocked to obtain diversion. The possibility of using such an arrangement with the control lines sequenced vertically in a timing jar that is fed fluid by a calibrated wick would allow a sampler with absolutely no moving parts and requiring no power other than from the fluid flow itself.

Freeman Automatic Sampler Evaluation

1. Should be free from clogging. Sampling intake must be designed by user.
2. Sampler itself offers no flow obstruction.
3. Should operate well over entire range of flow conditions.
4. Movement of solids should not hamper operation.
5. Continuous flow serves a self cleaning function. No cross-contamination.
6. Collects adjustable size (up to 1 quart) discrete samples at preset time intervals.
7. Ability to collect samples of floatables and coarser bottom solids will depend upon design of sampling intake.
8. No refrigerator. Adequate sample protection for this installation.
9. Not designed for manhole operation as presently configured.

10. Cannot withstand total immersion.
11. Unit should be able to operate in freezing ambients.
12. Operating head is provided by user.

SECTION VIII

EXPERIENCE WITH COMBINED SEWER SAMPLERS

In order to assess the efficacy of both standard commercially available samplers and custom engineered units in actual field use, a survey of recent EPA projects in the storm and combined sewer pollution control area was conducted. Final reports were obtained where available, but for some projects only interim reports existed and, in a few instances, telephone conversations had to be relied on. In each project, the research and development contract or grant was for an activity which also required determination of water quality. No projects have been undertaken solely to compare or evaluate samplers for use in storm and combined sewers.

STRAINER/FILTER TREATMENT OF COMBINED SEWER OVERFLOWS

Reference 8 is the final report for a project to examine strainer/filter treatment of combined sewer overflows. Although automatic sampling equipment was not used in this project, several interesting observations were made. It is stated in the conclusions that "this feasibility study has shown that sampling methods commonly used in evaluating the effect of combined sewer overflows on receiving streams cannot be considered reliable. The results indicate that most of the calculated loads that are based on automatic sampling stations have most likely understated the actual case". Particular criticism is leveled against the small diameter, low velocity probes which are characteristic of most present-day automatic sampling units. In this project the sampling was performed manually by a technician at the overflow site. Samples were taken at 15-minute intervals during the first 2 hours of flow and thereafter at 30-minute intervals for 2 hours. The samples were discrete in nature, not composits over each time interval, and were taken in two quantities: a) 2-gallon sample taken with a 1-gallon pail, and b) a 1-gallon sample taken with a 1-pint wide-mouth cup. The samples were brought to the analytical laboratory within 6 hours of the initial sampling time.

It is noted on page 18 that visual observation of several overflows conclusively showed the presence of fresh human feces (larger than one-half inch) and whole pieces of toilet paper. Samples were also collected using a wire mesh screen with one-quarter inch openings. Comparison of the suspended solids in the usual pail samples with those collected on

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wire mesh strainers consistently showed a variation in particle size. Only when a sample was taken at the surface of the flowing stream did the maximum particle size obtained with the pail equal that found with the wire mesh strainer.

In one instance a set of samples was taken by two people simultaneously at the same surface depth. The pail sample was found to have consistently higher values than the scoop sample for each variable tested. These variables included BOD, COD, suspended solids, total solids, volatile solids and settleable solids. In some instances the analyses of the scoop obtained samples resulted in values less than half of those obtained from pail collected samples. Although whole sections of toilet paper were noted in the overflow, the sampling technique used did not produce or yield any paper in the samples. Since a double sheet of toilet tissue weighs approximately 0.37 grams and would yield a COD value of approximately 19,400 mg/l, the impact on analytical results is obvious.

STREAM POLLUTION ABATEMENT FROM COMBINED SEWER OVERFLOWS

Reference 9 contains the results of a detailed engineering investigation and comprehensive technical study to evaluate the pollution effects from combined sewer overflows on the Sandusky River at Bucyrus, Ohio. The overflows from many storms were sampled during the study period to determine the quality of the overflow and pollution loads. For about 6 months samples were collected manually. After February 1, 1969, Serco automatic samplers, Model NW-3, were installed in the instrument shelters at the overflows. These samplers collected a 300 ml sample every 5 minutes for 2 hours during overflow. If the overflow continued longer than 2 hours, samples were collected manually at less frequent intervals.

It is noted on page 15 that an automatic starter was devised for the samplers that started the clocks when the water level reached a pre-determined height behind the weirs. The samplers could therefore be left unattended prior to and during an overflow. The samplers required a vacuum to be maintained in the sample bottles. Because the samplers would lose vacuum after 1 or 2 days, they had to be installed in the 24 hours preceeding the overflow.

Except for these comments regarding difficulty with automatic starters and vacuum leaks, no other in-service related problems were mentioned.

CONTROL OF POLLUTION BY UNDERWATER STORAGE

Reference 10 contains the results of a demonstration project for the control of pollution by underwater storage. A pilot plant was designed, constructed and operated to assess the feasibility of providing a facility for the collection, treatment, storage and final disposition of storm overflow from a combined sewer system. A Serco Model NW-3 automatic sampler was located at the Parshall Flume. It was found to be inadequate for the requirements of the testing laboratories. The sampling quantities required were four times greater than that originally contemplated. As a result, samples were taken partly with the automatic sampler, but primarily by hand. No other comments of the suitability of this sampler for its application or experience with it were made.

ENGINEERING INVESTIGATION OF SEWER OVERFLOW PROBLEMS

Reference 11 contains the results of an engineering investigation of sewer overflow problems in Roanoke, Virginia. Both manual and automatically gathered samples were obtained during storm events to assess the quality of sewer overflows and storm runoff. Serco automatic samplers were used in this program. The problems encountered during sampling primarily involved the equipment. It is noted on page 149 that the automatic samplers worked rather well, except that some precautions had to be taken. In the streams the nozzle could not be rested on the bottom, or sand and grit would be drawn in the sample bottle. Rags from the sanitary sewers would block several of the tube openings during a 24-hour sampling program. Occasionally a clock would stop and a complete rainfall would be missed. The automatic starting devices proved to be inadequate; therefore, the samplers had to be started manually at the beginning of each rainfall which proved to be time-consuming.

MICROSTRAINING AND DISINFECTION OF COMBINED SEWER OVERFLOWS

Reference 12 contains the results of an investigation of microstraining and disinfection of combined sewer overflows. On page 20 it is noted that composite samples of the raw and strained water were extracted automatically by two N-Con Surveyor model samplers and stored in refrigerated containers. The samplers were adjusted to withdraw portions of the flows at a fixed rate every 6 minutes. The only comments made about the sampling equipment were that composite sampling is not so representative of variations within a storm and discrete samples would be more desirable, and a complaint about the low suction lift which restricted operations.

In Phase II of this project reported in (12a) automatic vacuum-type discrete samplers (Serco Model SG-15) were used. The samplers collected discrete 300 ml samples of influent and effluent every 2 minutes. The data on organic content and coliform from 14 storms were rendered useless due to improper sterilization of the samplers in the field. Sampler failures were noted but not discussed.

STORMWATER POLLUTION FROM URBAN LAND ACTIVITY

Reference 13 presents the results of an investigation of the pollution concentrations and loads from storm water runoff in an urban area of Tulsa, Oklahoma. Standard procedures for manual sampling were used when baseline samples or stormwater runoff samples were collected. The stationary automatic sampling method was used when a time series of samples was desired. The sampling apparatus employed was unique and custom-designed for this project by the contractor. Five semi-stationary automatic sampling stations and three portable automatic samplers were fabricated and used in this project. The only problems noted were due to vandalism. Several of the semi-stationary sampling stations were broken open and some of the equipment was damaged. This caused important data losses on some watersheds.

RETENTION BASIN CONTROL OF COMBINED SEWER OVERFLOWS

Reference 14 contains an evaluation of the control of combined sewer overflows by retention in an open basin in Springfield, Illinois. It is interesting to note that the instrumentation subcontract cost was $31K, while the subcontract for construction of the basin itself only cost $77K. A rather large scale fixed installation, automatic sampling system was designed for this project. Originally 4-inch diameter influent and effluent sampling lines were used. Pumps took suction from the sampling lines and discharged in the sampling tanks. A Trebler scoop-type sampler was provided in each tank to take the samples. Samples of equal volume were taken at 30-minute intervals with the automatic samplers and composited over a 24-hour period. The composite bottles were located in a refrigerator and were kept under mechanical refrigeration at all times.

Problems were experienced with operation of the samplers during early months of the operation. This was particularly true of the influent sampler. The influent sampling line was over 900 feet long. It was concluded that this 4-inch diameter line was much too large for the size pump taking suction from it and, as a result, considerable amounts of solids settled in the line. This provided a non-representative sample of the influent. There were also difficulties associated with the location of the influent sampler probe. As a solution, the 4-inch influent sampling line was replaced with a 1.5-inch diameter line. This provided better velocities in the line and minimized settling of solids in it. A listing of maintenance items required over a 1-year period of operation is given on page 31. It is noted that there was one instance of repair on the flowmeter, seven instances of influent sampling line repair, one instance of effluent sampling pump repair, one instance of influent sampler motor burnout and replacement, three instances of repair for both pumps, and eight instances when the influent sampling line needed to be unclogged.

CHEMICAL TREATMENT OF COMBINED SEWER OVERFLOWS

Reference 15 contains the results of a study of flocculant treatment and disinfection of combined sewer overflows at Grosse Point Woods, Michigan. It is noted on page 48 that one of the most difficult problems was that of sampling. Flow rates varied from 305 to 2,450 cubic feet per second. Influent sewage depths varied from 2 to 17 feet with no dry well available for positive head devices, and a representative effluent sample had to be obtained from an inaccessible weir approximately 210 feet in length.

All main sampling lines in the final design were 2 inches in diameter and flowed constantly during the sampling period. Because of the importance of sampling, automatic samplers were designed and constructed specifically for work on this project. These samplers were designed to collect adjustable grab samples from the continuously flowing 2-inch pipe stream, composite them for various periods, and hold them in a refrigerated compartment for periods up to about 3 hours. No discussion of problems encountered with these sampling devices was given.

COMBINED SEWER TEMPORARY UNDERWATER STORAGE FACILITY

Reference 16 contains the results of a demonstration of the feasibility of utilizing a temporary underwater storage facility as a means of abating pollution resulting from storm overflow from a combined sewer. Conclusion number 5 is especially interesting: "The samplers utilized on the project are not recommended for the sampling of sewage from combined sewers. A more advanced and efficient sampling method should be developed for future programs." On page 32 it is noted that "the required volume per sample was 1,020 ml to perform all required analyses. The standard

Serco Model NW-3 automatic sampler would collect approximately 330 ml of sample per bottle when operated with a 5 foot lift, and 26 inches mercury internal vacuum and an atmospheric pressure of 30 inches mercury. Therefore, it was necessary to fill four bottles at a time for adequate sample volume". A newly designed and fabricated tripper arm was installed on the Serco sampler. The tripper arm simultaneously actuated four sampling line switches. A 15-minute gearhead was utilized for the tests to provide a sampling interval that would not overtax the field laboratory beyond its capacity.

URBAN RUNOFF CHARACTERISTICS

Reference 17 is an interim report on investigations for the refinement of a comprehensive EPA stormwater management model in which urban runoff characteristics are to be depicted. As a part of this program, automatic equipment for sequential sampling of water quality was installed for five separate sewer locations in the Bloody Run Sewer Water Shed in Cincinnatti, Ohio. N-Con Sentry Sequential Effluent Samplers were used in this program. The large amount of data given in the report indicates a generally satisfactory collection of samples but no operational comments are given.

IN-SEWER FIXED SCREENING OF COMBINED SEWER OVERFLOWS

Reference 18 reports on a project to examine the feasibility of in-sewer fixed screening of combined sewer overflows. As a part of this effort, a field sampling and analysis program supplemented with laboratory studies was conducted to characterize combined sewage contributory to combined sewer overflows, and to ascertain the removal of floatables and solid materials that could be effected by the placement of the screening devices in these systems. For this program special sampling equipment and supporting structures were designed and manufactured in order to assure representative collection of combined sewage samples. The equipment consisted of two types of samplers: a bulk liquid sampler and a screening sampler. Both employed the same support structure and the same sampling manhole. These are essentially bulk grab samplers which allowed removal of an entire 1 foot long section of combined sewage flow in the sewer. The sampler is lowered by hand and raised by a winch. Samples were collected on an hourly basis. No comments are made about the operational experience with these samplers, but apparently no difficulties were encountered.

STORM AND COMBINED SEWER POLLUTION SOURCES AND ABATEMENT

Reference 19 is a report on a study of six urban drainage basins within the city of Atlanta which were served by combined and separated sewers. As a part of the effort to determine the major pollution sources during storm events, automatic sampling devices were used. The Serco Model NW-3 Sampling Device was used, but several difficulties are indicated. On page 4 several interesting conclusions are noted: "Samples collected by automatic sampling devices tended to freeze in the sampling tubes during cold weather. Furthermore, the location of these vacuum operated devices at safe heights above peak flow levels limited the volume of samples that could be collected." "The automatic triggering device utilized during this study was not reliable. Dampness deteriorates electrical contacts and solenoids causing failure of apparently well insulated parts. The consequent necessity for manual triggering of the automatic samplers reduces their usefulness and indicates the need for an improved triggering device." "No significant differences exist between water quality analyses of simultaneous samples obtained by grab and automatic sampling techniques."

STORM WATER PROBLEMS AND CONTROL IN SANITARY SEWERS

Reference 20 is a report of an engineering investigation which was conducted on stormwater infiltration into sanitary sewers and associated problems in the East Bay Municipal Utility District with assistance from the cities of Oakland and Berkeley, California. Grab samples were collected with a rope and a bucket. Wet weather samples were collected with an Edison Lever Action Diaphragm Pump with a 1 1/2 inch suction line. Two types of portable samplers were used for dry weather flow; the Hinde Effluent Sampler which has a positive displacement pump with a 20-foot lift and an N-Con Surveyor automatic composite sampler. The only real difficulty encountered in using the automatic samplers was that the suction tubing was so small that stringy and large size material tended to plug the lines. This problem was circumvented by placing a 20-mesh galvanized wire fabric stilling well around the ends of the suction tubes. Also it was not possible to obtain samples automatically at one location because its 24 foot depth exceeding the lift capacity of the samplers. It is noted on page 61 that the results of the analyses which were conducted on the samples gathered with the automatic sampling equipment were somewhate erratic.

UNDERWATER STORAGE OF COMBINED SEWER OVERFLOWS

Reference 21 is a report of a demonstration study of offshore underwater temporary storage of storm overflow from a combined sewer. It is interesting to note that one of the recommendations given on page 3 is that, "collection of grab samples of all flows should be used liberally to confirm results from automatic samplers." The sampling program included grab samples for the dry weather flow, individually timed samples and composite samples of the storm overflow from the combined sewer drainage area, composite samples of effluent from the storage tanks, and grab samples of bay water at the outfall. At the time of design no sampler was commercially available to do the required job and at the same time secure a representative composite sample. Therefore a sampler was designed and constructed especially for this program. No operational data regarding this sampler are given but apparently no great difficulties were encountered.

MAXIMIZING STORAGE IN COMBINED SEWER SYSTEMS

Reference 22 is a report on maximizing storage in combined sewer systems in the municipality of Metropolitan Seattle. Programmed automatic-refrigerated samplers were designed and built as a part of the demonstration grant to simplify the sample collection tasks. These were manufactured by Sirco and were their Sewer-Test Vary-Sampler models. The report notes that, "the connotation of the term 'automatic' is somewhat deceiving; considerable manual effort is involved in collecting samples, replacing bottles and testing and repairing the various electrical components". Originally the samplers were supervised, maintained and serviced by different personnel. On the newly designed samplers, there was a 6-month period during which the samplers were broken in and various parts changed or modified. A single technician was assigned supervisory, service and maintenance responsibility for each of the automatic samplers and, since then, performance has been satisfactory.

A number of sampler problems were encountered including the electrical system which was quite complicated, the wiring which was difficult to maintain, instances of inadequate fuses, and failures of timers, microswitches, relays and reed switches. It is also noted that despite an automatic purging feature, the 3/8-inch diameter sampling tubes often became clogged with rags and other debris and required constant checking. During periods of extremely high flows, the sampler tubes were often flushed over emergency overflow weirs and left hanging high and dry when the flow subsided.

After the reporter's extensive history with the use of these samplers, two of the conclusions were especially noteworthy; "Samplers and recorders to be effective require regular surveillance and maintenance. The smallest failures can reduce valuable data to a level that is unuseable for certain statistical analyses." "The best sampling equipment is generally the least complex, is portable, does not require lines, constrictions, or bends, and is not likely to become damaged when submerged (a large order)."

OTHER EPA PROJECTS

Among EPA projects surveyed for which final reports are not available is a project (EPA No. 11023 FAT) for the construction , operation and evaluation of a stormwater detention and chlorination station to treat combined sewer overflows on the Charles River in Boston, Massachusetts. Operation of the station commenced in early summer of 1970. Two Pro-Tech, Inc., Discrete Flow Samplers, Model DEL-240, are installed for obtaining discrete samples of inflow to the plant. These can be adjusted to sample at various time intervals from 1 minute to 24 hours. In a recent telephone conversation with the engineer in charge of the facility, it was learned that numerous troubles were experienced with the samplers during early operation. After various adjustments and modifications by the maunfacturers the samplers operated satisfactorily. The specific nature of the troubles experienced was not discussed, but will be reported by letter.

In a project (EPA No. 11023 FAS) for the chlorination of a large volume of stormwater draining to Lake Pontchartrain in Louisiana, seven samplers were designed and constructed specifically for the project. Difficulty was experienced with solenoid operation of a brass valve. Apparently, satisfactory operation was attained after redesigning the valve in PVC. Initially, a telephone tone was used to start and stop the samplers. This method of actuation did not prove to be satisfactory and was discontinued. Information concerning these samplers was obtained by telephone conversation with the project engineer.

In a project (EPA No. 14-12-24) for the demonstration of a method of treating municipal sewage with a device termed a "rotating biological contactor", Serco automatic samplers were used for sampling in the treatment plant. Apparently, under the controlled plant conditions, performance of the sewer samplers was satisfactory. A "rotating belt sampler", custom built for the project, was used to sample wet weather flows to the plant. Samples were obtained "by means of a mechanical sampler installed in a drop manhole in the street. A series of sampling cups was driven along a belt to collect 250 ml samples about every 15 minutes during the combined flow. The sampler was actuated by the flow measuring device and was stopped by a limit switch when the first sample reached the drive system near the top of the manhole. Records collected for the project show that the device operated on 18 days during periods of fairly small flow (under 10 cubic feet per second).

In a grant project (EPA No. 11023 DXC) for the characterization and treatment of combined sewer overflows in San Francisco, California, a unique partially hand sampling device was used. A 12-inch pipe core, set in pipe guides, is dropped to the bottom of the channel with its cover open. Thus a partially integrated sample is forced into the pipe. The cover is then closed and the sample is surfaced by means of compressed air.

In a grant project (EPA No. 11020 FAX) to demonstrate system control of combined sewer overflows in a large urban area, an automatic sampler manufactured by Rock and Taylor of Birmingham, England, was used. Megator Corporation, Pittsburgh, Pennsylvania, is distributor of the sampler. It is of suction type with a maximum lift of 18 feet, operating on a 12-volt battery or 120 volts, ac. Performance of this sampler was continually troubled by blockage due to papers, rags, disposable diapers, etc. Such troubles are described in project reports during most months of operation. After a period of freezing during the winter, use of the automatic sampler was discontinued, and hand sampling was substituted.

SECTION IX

STATE-OF-THE-ART ASSESSMENT

As can be noted from a review of the preceding sections, despite the plethora of automatic liquid sampling equipment that is available today, none is eminently suited for a storm and/or combined sewer application. An assessment of the current state-of-the-art from the technological viewpoint is in order to indicate where and how improvements can be made and to give design guides for the development of new automatic samplers. The material is arranged in subsections which deal with each of the basic sampler functions, and the emphasis is on technical considerations to assure satisfactory execution of each function. The functions are interrelated, however, and the designer must use a systems approach in his synthesis and analysis activities.

SAMPLER INTAKE ASSESSMENT

The sample intake of many commercially available automatic liquid samplers is often only the end of a plastic suction tube, and the user is left to his own ingenuity and devices if he desires to do anything other than simply dangle the tube in the stream to be sampled. In the following paragraphs we wish to examine the functions of a sampler intake that is intended to be used in a storm or combined sewer application and the design considerations that arise therefrom.

Pollutant Variability

A general discussion of the character of storm and combined sewage is given in section III where the variability of pollutant concentration is also treated. We wish to consider the latter factor here in somewhat more detail. Let us consider first some empirical data from (23). In the study, a special pressurized circulating loop was assembled containing a 10-inch square test section some 15 feet long. Careful measurements of the velocity contours were made and near uniformity was observed. From figure 18, which shows such velocity contours for a nominal 5 fps velocity flow, it can be seen that the velocity one-half inch from the wall exceeds 4.5 fps everywhere except near the corners. Since the variability of a pollutant will be a function of velocity variations (among other factors), it is of interest to note the horizontal and vertical variations of sediment distribution observed experimentally in this test section with its very small velocity variation.

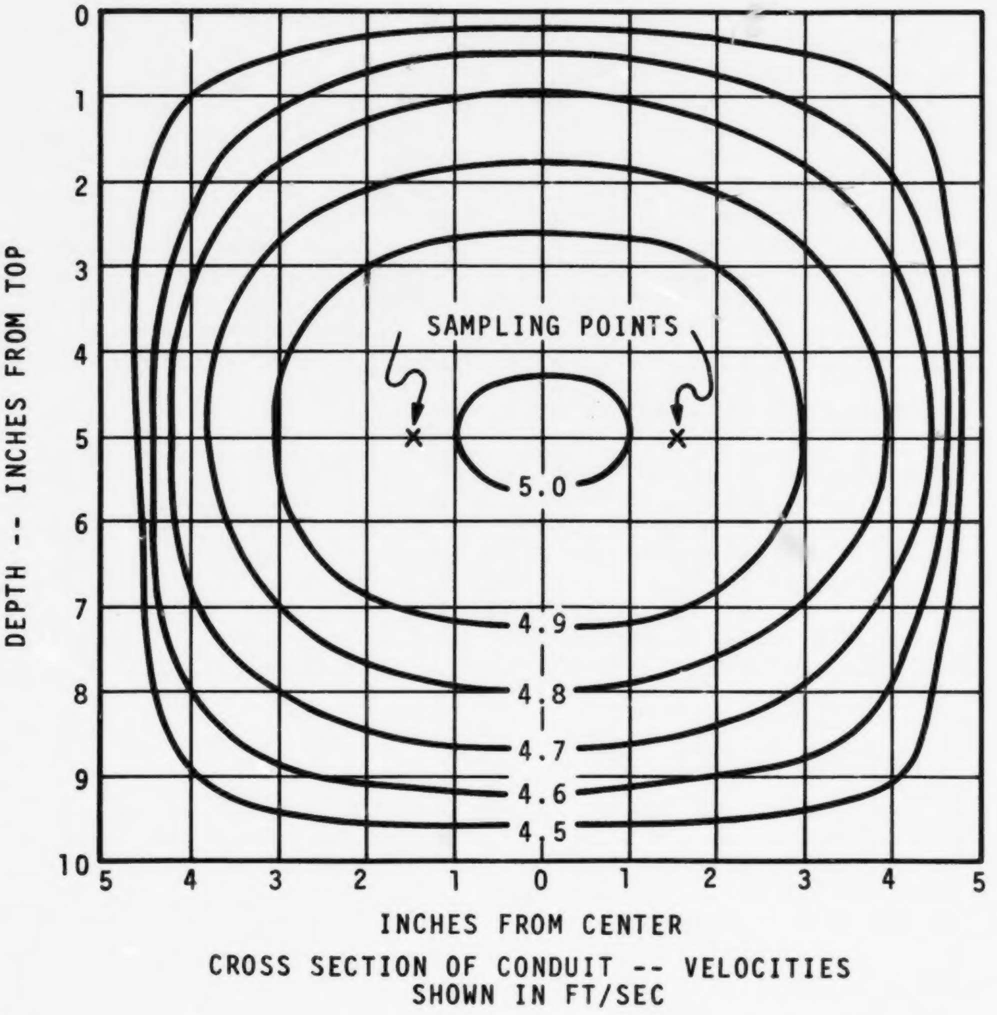


Figure 18. Velocity Contours at Sampling Station*

* Taken from reference 23.

Four readily available commercial sands, differing principally in size, were used in the study. They are referred to by mean particle size (50 percent finer by weight) as 0.45 mm, 0.15 mm, 0.06 mm and 0.01 mm. Observed sediment distribution for the three coarsest sands are indicated in figure 19. For all practical purposes the 0.01 mm sand was uniformly distributed. It should be noted here that the vertical variation is probably enhanced due to the design of the test loop, which would tend to enhance concentrations of heavier particles to the outside (the bottom of the test section in this case) due to the action of centrifugal forces. Observations made in (7) indicate this effect rather effectively. In their test set-up an 8-foot wide flume was narrowed to an 18-inch test section by placing an insert in the flume bed along the wall opposite to that from which samples were to be extracted. Although the reduction in width occurred some 36 feet upstream of the sampler inlet, for the 0.45 mm sand used in the investigation, concentrations at 1 inch from the wall were found to be two to four times greater than at 3 inches from the wall. Similar but less pronounced horizontal concentration gradients were observed for the finer sands as well.

The observation was made in (7) that, in addition to variations in sediment concentration within the cross-section at a given time, the sediment concentration at any point in the cross-section was highly variable with respect to time, especially for the coarser sediments (0.45 mm). This observation was also made in (23) where data are presented on concentration variation with respect to time as a function of sampling interval. The concentration of successive 20-second samples was found to vary over a range of 37 percent of the mean, and the concentration of successive 60-second samples varied over a range of 10.5 percent. Such variations arise from the natural turbulence of the flow as would be encountered in an actual sewer and from the non-uniform nature of re-circulated flows in test loops which is peculiar to laboratory simulations.

So far we have focused our attention on relatively heavy (specific gravity approximately 2.65) solids and their distribution in a flow. For the lighter organic solids with specific gravities near unity, the particle distribution will be more nearly uniform in a turbulent flow. It would appear that one can expect a reasonable degree of uniformity in the distribution of particles which fall in the Stokes' Law range of settling velocities, i.e., for values of the external Reynolds' number less than unity. If one describes

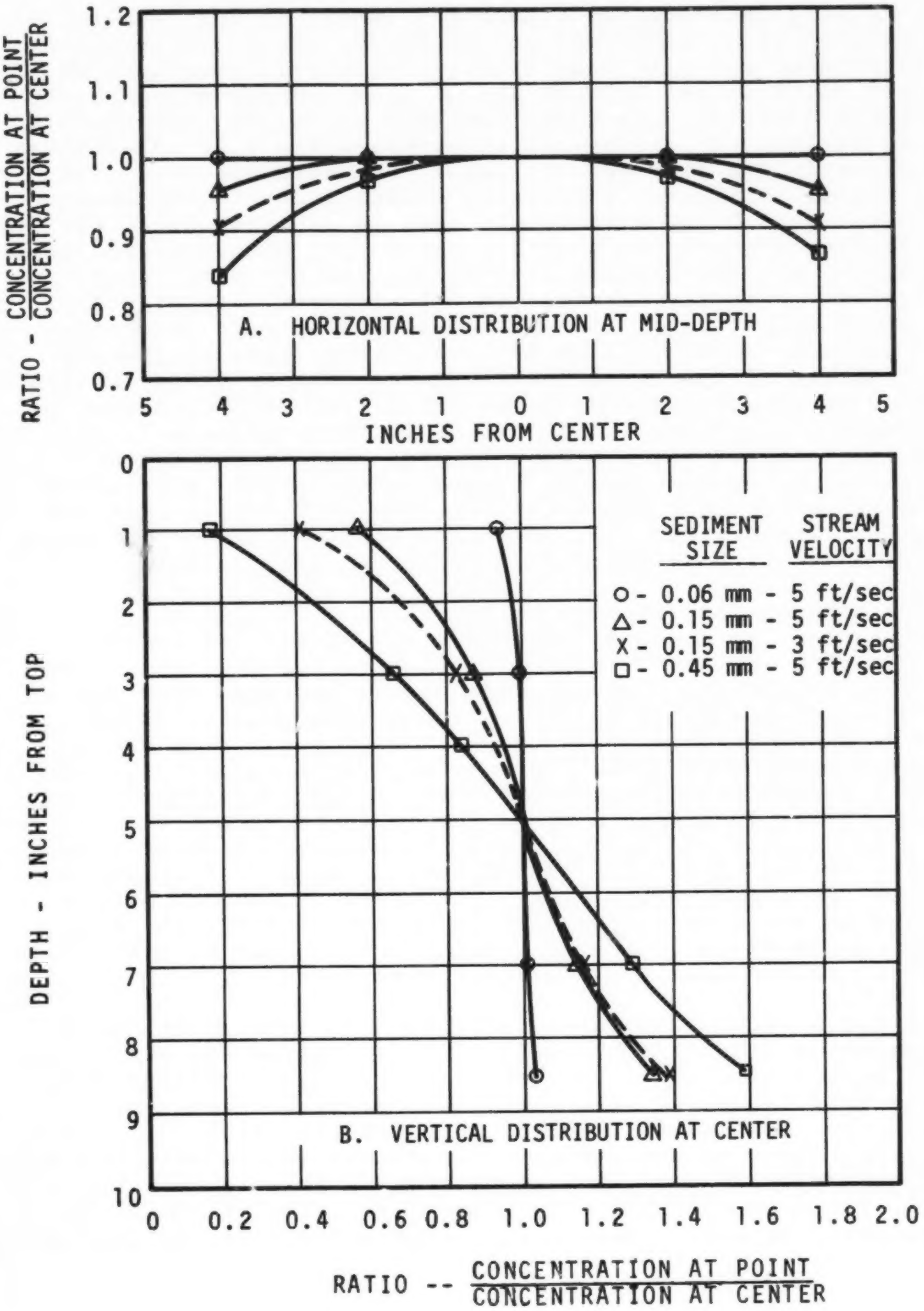


Figure 19. Sediment Distribution at Sampling Station*

* Taken from reference 23.

a particle in terms of its hydraulic size W, defined as the velocity of uniform fall in a fluid at rest, Stokes' Law can be written as

$$W = gd^2 (s.g.-1)/18\nu \tag{1}$$

where d is mean particle diameter, s.g. is the specific gravity of the particle material, ν is the kinematic viscosity of the fluid, and g is the acceleration of gravity. The external Reynolds' number (so called because the linear dimension upon which it is based is a particle dimension rather than a flow dimension) can be expressed as

$$Re = Wd/\nu \tag{2}$$

Combining equations (1) and (2) we can express the range of validity of Stokes' Law as

$$Re = gd^3 (s.g.-1)/18\nu^2 < 1 \tag{3}$$

If one considers water at 60°F as the fluid ($\nu = 1.217 \times 10^{-5}$ ft^2/sec), a plot of equation (3) over the range of interest is given in figure 20. Here it can be noted that, within the range of Stokes' Law, the maximum particle diameter for sand with a specific gravity of 2.65 is less than 0.1 mm while for organic particles with a specific gravity of 1.05 it is about 0.3 mm.

Since the kinematic viscosity of water is temperature dependent, the Stokes' Law particle diameter limit will also be a function of temperature. A typical plot of this variation is given in figure 21 for sand with a specific gravity of 2.65 and Re=1. Here it can be noted that a decrease in water temperature from the upper eighties to the mid-forties results in a 50 percent increase in the maximum particle diameter.

Sampler Intake Functions

The operational function of a sampler intake is to reliably allow gathering a representative sample from the flow stream in question. Its reliability is measured in terms of freedom from plugging or clogging to the degree that sampler operation is affected and invulnerability to physical damage due to large objects in the flow. It is also desirable, from the viewpoint of sewer operation, that the sampler intake offer a minimum obstruction to the flow in order to help prevent blockage of the entire sewer pipe by lodged debris, etc.

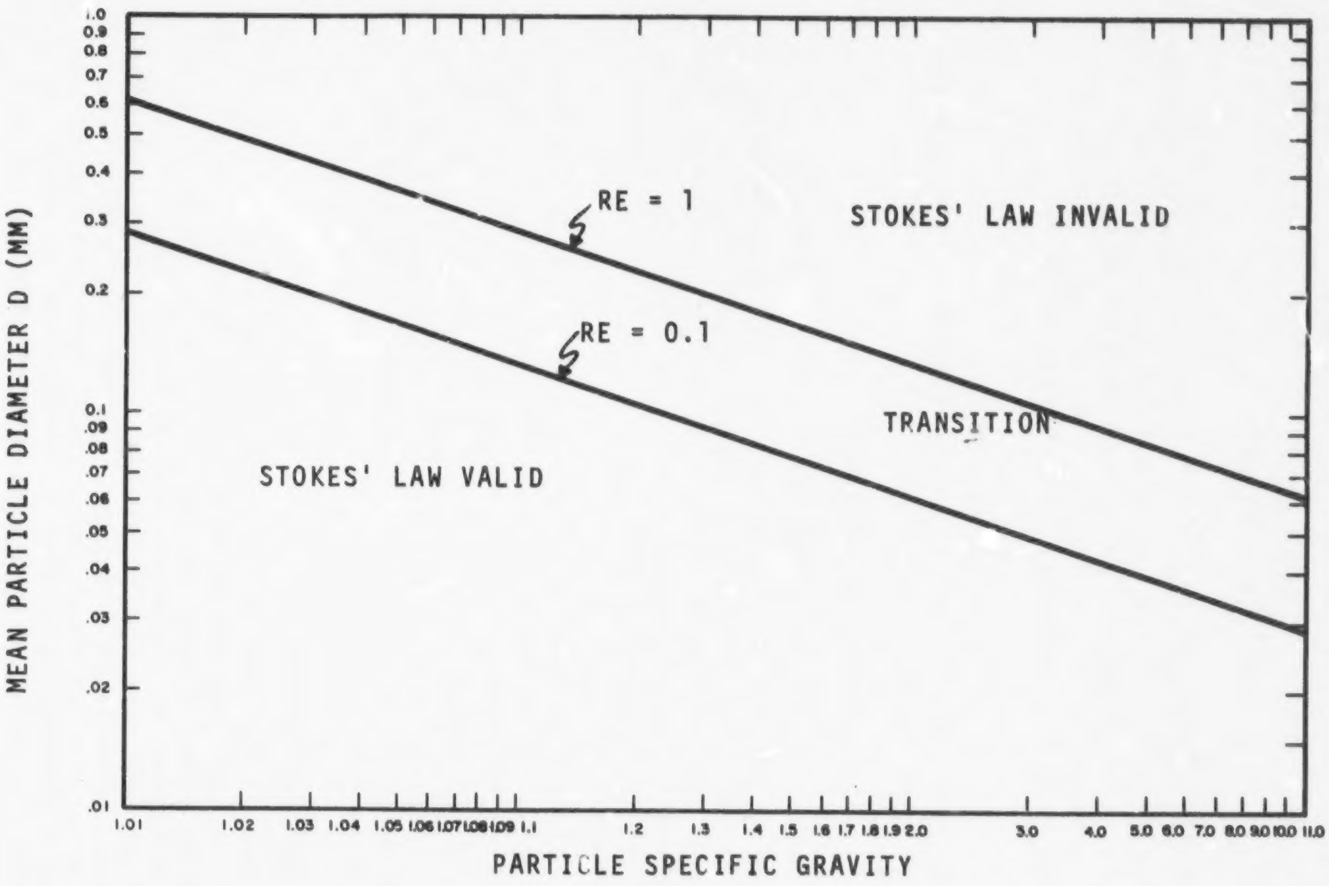


Figure 20. Region of Validity of Stokes' Law

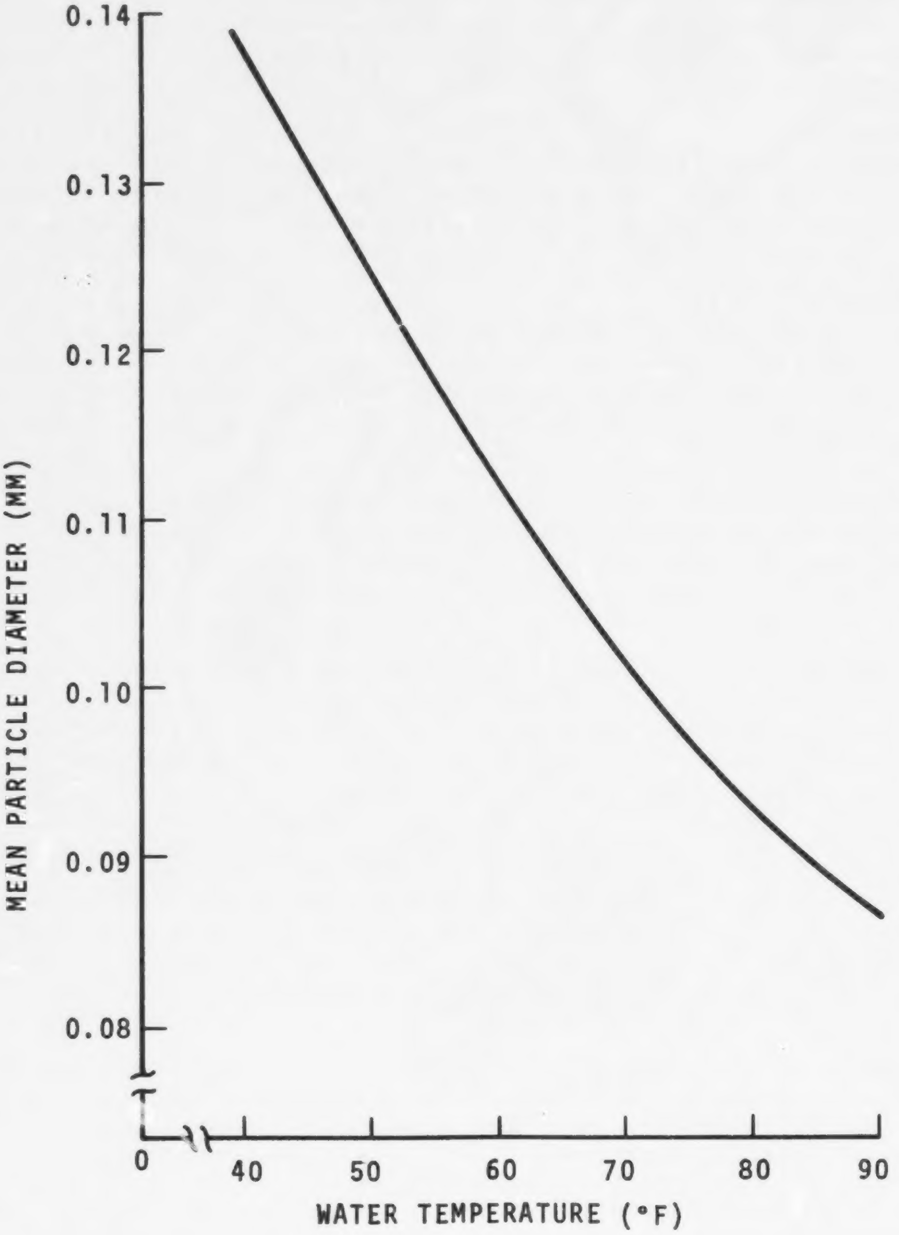


Figure 21. Effect of Temperature on Maximum Particle Size

Let us first consider the ability of the intake to gather a representative sample of dense suspended solids in the sediment range, say up to 0.5 mm with specific gravity of 2.65. The results of a rather thorough examination of relatively small diameter intake probes (1/4" and 1/8" I.D.) are given in (23). The argument is developed that, for a nozzle pointing directly into the flow, the most representative sample of a fluid/suspended-solids mixture will be obtained when the sampling velocity is equal to the flow velocity at the sampling point. Using this as the reference criteria, investigations were conducted to determine the effects of a) deviations from the normal sampling rate, b) deviations from the straight-into-flow position of the probe, c) deviations in size and shape of the probe, and d) disturbance of sample by nozzle appurtenances. The effect of the sampling velocity on the representativeness of the sample is indicated in figure 22 which presents the results for 0.45 mm and 0.06 mm sand. For the latter size, which falls within the Stokes' Law range, less than ±4 percent error in concentration was observed over sampling velocities ranging from 0.4 to 4 times the stream velocity. For the 0.45 mm particles, the error at a relative sampling rate of 0.4 was +45 percent, and at a relative sampling rate of 4 the error was -25 percent.

For probe orientations up to 20° to either side of head-on, no appreciable errors in concentration were observed. Similarly, introduction of 0.150- and 0.375-inch probes showed comparatively little effect on the representativeness of the sample. The probe inlet geometry, i.e., beveled inside, beveled outside, or rounded edge, also showed little effect on the representativeness of the sample, when compared to the standard probe. Finally, in instances where a sampler body or other appurtenance exists, the probe should be extended a short distance upstream if a representative sample is to be collected. In summary, it was found that for any sampler intake facing into the stream, the sampling rate is the primary factor to be controlled.

Tests were also run with the sampling intake probes in the vertical position to determine the effect such an orientation had upon the representativeness of the sample. With such intakes, the sample entering them must undergo a 90° change of direction, and consequently there is a tendency for segregation and loss of sediment to take place. Tests were run with the standard probe, an orifice (1/4-inch diameter) in the center of a 1- by 2-inch flat plate oriented so that its longest dimension was in the direction of flow,

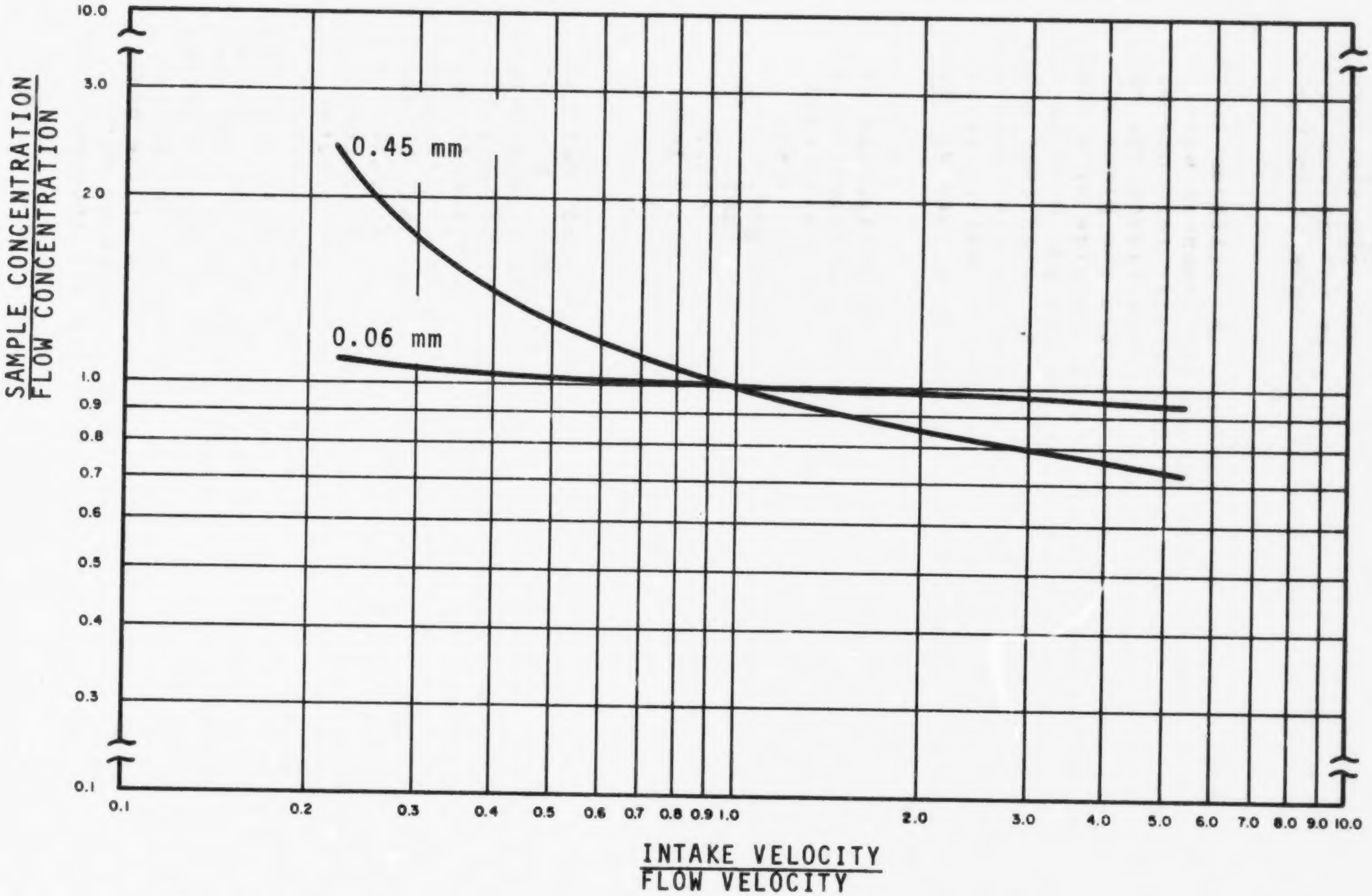


Figure 22. Effect of Sampling Velocity on Representativeness of Suspended Solids*

* Data from reference 23.

and with an orifice in a crowned (mushroom shaped) flat plate 1 1/4 by 2 inches. The results all showed negative errors in concentration, increasing with particle size and increasing with intake velocities less than the stream rate but nearly constant for intake velocities higher than the stream rate.

Since the smallest errors were found for the orifices in the flat and mushroom shaped plates (whose performances were nearly identical for intake velocities greater than one-half the stream velocity), it was decided to investigate the effect of lateral orientation, i.e., to rotate the plate 90° so that it might represent an orifice in the side of a conduit rather than in the bottom. The results for 0.15 mm sand are presented in figure 23. It can be noted that while the side orientation caused greater errors (as was to be expected), these errors approached the nearly constant error of the 0° orientation as the relative sampling rate was increased above unity.

The work reported in (7) was a laboratory investigation of pumping sampler intakes. Nine basic intake configurations, all representing an orifice of some type in the side wall of the flume, were examined. They included 1/2-, 3/4-, 1- and 1 1/2-inch diameter holes with square edges, 3/4-inch diameter holes with 1/8- and 1/4-inch radii, 1/2- by 1-inch ovals, one oriented vertically and the other horizontally, and a 3/4-inch diameter hole with a 2 inch wide shelf just under it. Sand sizes of 0.10 mm and 0.45 mm were used in the study.

Reference samples were taken with a probe located near the wall and pointing into the direction of the flow. The reference sample intake velocity was equal to the stream velocity. The primary measurement was sampling efficiency, the ratio of the sediment concentration in the test sample to that of the reference sample computed for a point 1/2-inch from the wall. The reference sample was taken just before and just after the test sample was gathered. Although the data exhibited considerable scatter, several conclusions were drawn. With regard to the intake velocity, greater than 3 fps is generally desirable and, for sands coarser than 0.2 mm, an intake velocity equal to or greater than the stream velocity is desirable. With regard to intake configuration, for intake velocities greater than about 3 fps the sampling efficiencies showed little effect of size of intake (range of 1/2" to 1 1/2" diameter), of rounding the intake edges, or of shape and orientation of the axis of the oval intake. Sampling efficiency was found to decrease with increasing particle size above 0.10 mm for all intakes

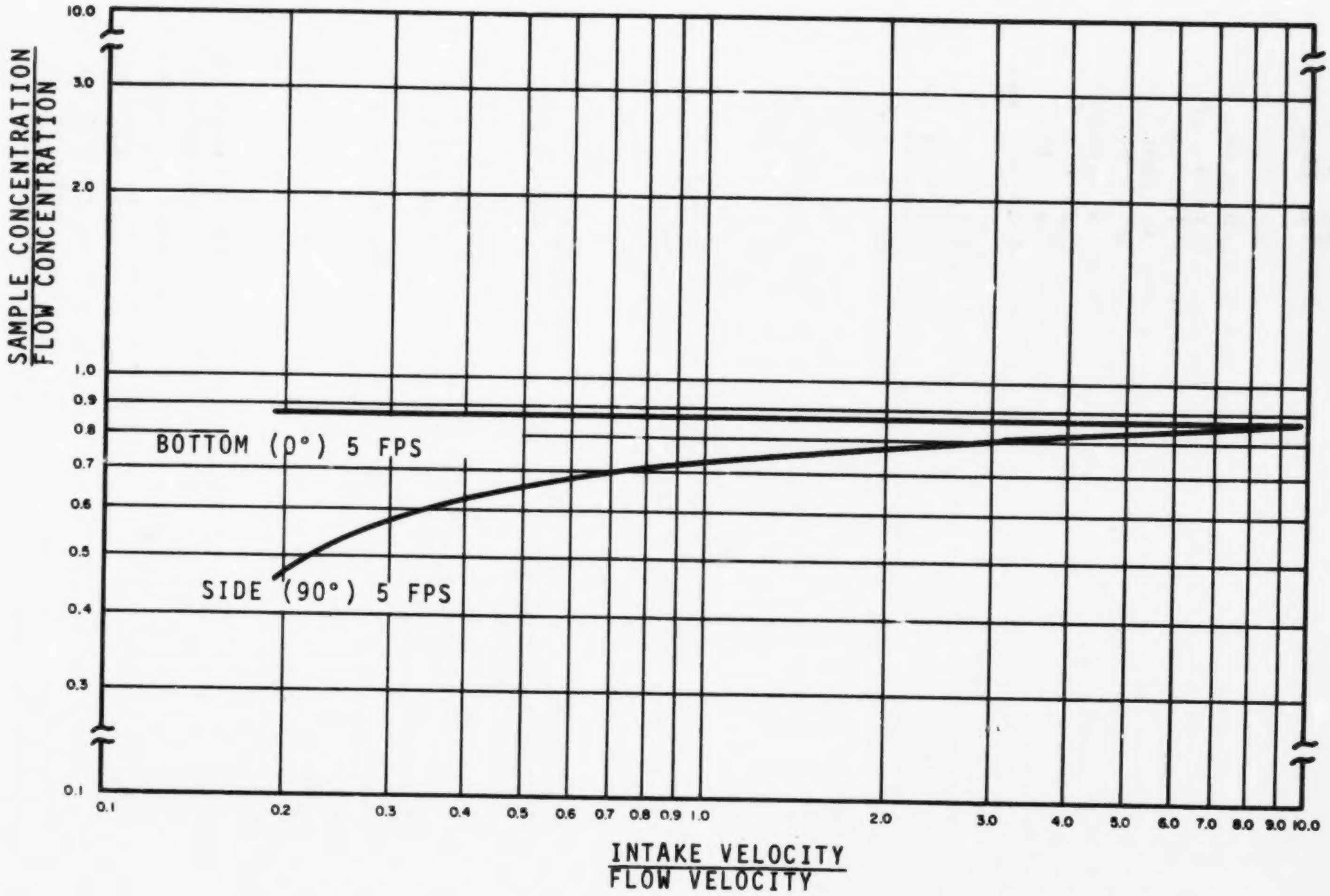


Figure 23. Effect of Lateral Orientation of Sample Intake*

* Data taken from reference 23.

tested. Finally, although the shelf intake showed somewhat higher sampling efficiency for coarse particles and high stream rates, its performance was very erratic over the entire range of test parameters.

Similar observations were made in field tests with river water samples at St. Paul and Dunning, Nebraska, reported in (24). In addition to the "standard" intake which was a flush mounted 1-inch pipe coupling, alternate intakes included 1- by 2-inch and 1- by 9-inch nipples; a 1- by 9-inch nipple with a 1/8 inch thick steel plate 14 inches high and 17 inches wide at its end; and a 1 inch street elbow with a 1- by 2-inch nipple oriented down, into the flow and up. It was concluded that the standard intake was as good as any in terms of sampling efficiency and was therefore preferable since it offered no obstruction to the flow and was therefore less vulnerable to damage by debris. The sediment being sampled was rather fine; in high flows 88 percent was finer than 0.062 mm and 100 percent was finer than 0.50 mm.

To summarize the foregoing as it relates to the sampler intake function of gathering a representative sample we note the following:

1) It becomes difficult to obtain a one-to-one representation, especially for inlets at 90° to the flow, for large, heavy suspended solids.

2) For particles that fall within the Stokes' Law range, consistent, representative samples can be obtained.

3) The geometry of the sampler intake has little effect on the representativeness of the sample.

4) The sample intake velocity should equal or exceed the velocity of the stream being sampled.

Sampler Intake Design

The foregoing suggest certain directions that the design of a sampler intake for storm and combined sewer flows should take. At the outset, it appears unwise to attempt to sample suspended solids that fall much outside the Stokes' Law range. A realistic maximum size for sand with specific gravity of 2.65 would appear to be around 0.1 mm to 0.2 mm. High sample intake velocities will be required, perhaps in excess of 10 fps, if the sample is to be representative.

Although the flow may be nearly homogeneous, except for very coarse solids and large floatables, more than one sample intake is desirable for reliability of operation as well as insurance against some unforeseen gradient in the pollutant. In view of the changing water levels in the conduit with changing flows, the changing velocity gradients within the flows, and the possibility of changing pollutant gradients not only with respect to these but also with type of pollutant; not even a dynamically adaptive sampler intake can be designed to gather a sample that is completely representative in every respect at the same time.

In order to better illustrate this point, let us consider a round pipe of radius R containing a flow at depth d and an arbitrary vertical concentration gradient of some pollutant.

Locate the origin of a cartesian coordinate system at the invert with the y axis positive upwards. We now assume that the pollutant concentration gradient can be expressed as a polynomial in y, i.e.,

$$p = \sum_n a_n y^n \tag{4}$$

The expression for the amount of pollutant in an arbitrary cross-sectional zone (say between depths y_1 and y_2) is

$$P = \iint \sum_n a_n y^n dxdy = 2 \int_{y_1}^{y_2} \sum_n a_n y^n \sqrt{2yR-y^2}\, dy \tag{5}$$

If one sets $P = \sum_n P_n$ the first few terms are;

$$\begin{aligned} P_o = a_o\Big\{&\Big[(y_2-R)\sqrt{2Ry_2-y_2^2} - (y_1-R)\sqrt{2Ry_1-y_1^2}\Big] \\ &+ R^2\Big[\sin^{-1}(y_2/R-1) - \sin^{-1}(y_1/R-1)\Big]\Big\} \end{aligned} \tag{6}$$

$$P_1 = 2a_1\left\{-\frac{1}{3}\left(2Ry_2-y_2^2\right)^{3/2} + \frac{1}{3}\left(2Ry_1-y_1^2\right)^{3/2} + \frac{RP_o}{2a_o}\right\} \tag{7}$$

$$P_2 = 2a_2\left\{y_2 - \frac{5}{12}R\left(2Ry_2-y_2^{\ 2}\right)^{3/2} - y_1 + \frac{5}{12}R\left(2Ry_1-y_1^{\ 2}\right)^{3/2} + \frac{5R^2P_o}{8a_o}\right\} \tag{8}$$

etc.

Using such a formulation one can obtain the values of y which divide the flow cross-section up into some number of zones each of which contains an equal amount of pollutant; let us designate them as $y_1, y_2, \ldots, y_m$. If one extracts a sample from the center of each zone, one can argue that its representativeness will be quite good, especially for large values of m. Unless the samples extracted from each zone are kept discrete, which would result in an inordinately large number of samples, the quantity of sample gathered from each inlet must be varied in accordance with the velocity gradient if the composite sample is to be representative in a mass transport sense. For a different concentration gradient p^1, one will obtain new values $y_1^{\ 1}, y_2^{\ 1}, \ldots, y_m^{\ 1}$ and hence different port locations and different quantities of sample required even for the same flow depth.

In view of the over-riding design mandate that simplicity maximizes probability of success, it becomes immediately apparent that the equipment sophistication implied by the foregoing would doom the design to operational failure if such a course were to be attempted. In the absence of some consideration arising from the particular installation site, a regular distribution of sampling intakes across the flow, each operating at the same velocity, would appear to suffice. Since the intakes should be as non-invasive as possible in order to minimize the obstruction to the flow and hence the possibility of sewer line blockage, it seems desirable to locate them around the periphery of the conduit.

GATHERING METHOD ASSESSMENT

As was noted earlier, three basic sample gathering methods or categories were identified; mechanical, suction lift, and forced flow. Several different commercial samplers using each method are available today. The sample lift requirements of the particular site often play a determining role in the gathering method to be employed. Some mechanical units were specifically designed for lifts to 200 feet. The penalty that one must trade-off in selecting a mechanical gathering unit is principally the necessity for some obstruction to the flow, at least while the sample is being taken. The tendency for exposed mechanisms to foul, together with the added vulnerability of many moving parts, means that successful operation will require regular, periodic inspection, cleaning, and maintenance.

Forced flow from a submersible pump also necessarily results in an obstruction to the flow. Pump malfunction and clogging, especially in the smaller sizes often used in samplers, remains a distinct possibility and, because of their location in the flow stream itself, maintenance is more difficult to perform than on above-ground or easily removable units. Pneumatic ejection is employed by several manufacturers, the gas source being either a compressor or bottled refrigerant. The latter units must necessarily be of small scale to avoid an enormous appetite for the refrigerant. The advantages of explosion-proof construction and high lift capability must be weighed against low line velocities, low sample intake velocities, and relatively small sample capacities.

Suction lift units must be designed to operate in the environment near the flow to be sampled or else their use is limited to a little over 30 feet due to atmospheric pressure. The necessity to have a pump that is free from clogging has led some designers to use peristaltic tubing pumps. Most of these operate at such low flow rates, however, that the representativeness of suspended solids is questionable. Newer high-capacity peristaltic pumps are now available and should find application in larger automatic samplers. The ability of some of these pumps to operate equally well in either direction affords the capability to blow down lines and help remove blockages. Also, they offer no obstruction to the flow since the transport tubing need not be interrupted by the pump, and strings, rags, cigarette filters and the like are passed with ease. With all suction lift devices a physical phenomenon must be borne in mind and accounted for if sample representativeness is to be maintained. When the pressure on a liquid (such as sewage) which contains dissolved gases is reduced, the gases will tend to pass out of solution. In so doing they will rise to the surface and entrain suspended solids in route. (In fact, this mechanism is used to treat water; even small units for aquariums are commercially available.) The result of this is that the surface layer of the liquid may be enhanced in suspended solids, and if this layer is a part of a small sample aliquot, the sample may not be at all representative. In the absence of other mitigating factors, the first flow of any suction lift sampler should therefore be returned to waste.

All in all, the suction lift gathering method appears to offer more advantages and flexibility than either of the others. The limitation on sample lift can be overcome by designing the pumping portion of the unit so that it can be separated from the rest of the sampler and thus positioned not more than 30 feet above the flow to be sampled. For the majority of sites, however, even this will not be necessary.

SAMPLE TRANSPORT ASSESSMENT

The majority of the commercially available automatic samplers have fairly small line sizes in the sampling train. Such tubes, especially at 1/8-inch inside diameter and smaller, are very vulnerable to plugging, clogging due to the build-up of fats, etc. For application in a storm or combined sewer, a better minimum line size would be 3/8- to 1/2-inch inside diameter.

It is imperative that adequate sample flow rate be maintained throughout the sampling train in order to effectively transport the suspended solids. In horizontal runs the velocity must exceed the scour velocity, while in vertical runs the settling or fall velocity must be exceeded several times to assure adequate transport of solids in the flow.

The complexities inherent in the study of a two-phase mixture such as soil particles and water are such that rigorous analytical solutions have not yet been obtained except in certain limiting cases such as the work of Stokes cited earlier. The use of hydraulic size, which is the average rate of fall that a particle would finally attain if falling alone in quiescent distilled water of infinite extent, as a descriptor for a particle involves its volume, shape and density. It is presently considered to be the most significant measurement of particle size. However there are no analytical relationships to allow its computation; recourse must be made to experiment. The geometric size of a particle can be based upon its projected lengths on a set of right cartesian coordinates oriented so that a is its major axis, b is its intermediate axis, and c is its minor axis. With patience and a microscope the lengths a, b, and c of a particle can be determined. Since the number of particle shapes is infinite, a system for classification is required. One put forth in (25) is the shape factor defined as:

$$SF = c/\sqrt{ab} \tag{9}$$

which approximately defines the shape in terms of three of a multitude of dimensions of an irregular particle. Of course there may be rounded, angular, smooth and rough particles all with the same shape factor.

An excellent discussion of the fundamentals of particle size analysis is given in (26). Table 3, which is taken from data presented therein, illustrates the effect of shape factor on hydraulic size for sand particles with specific gravity of 2.65 in water at 20°C. It can be noted that while a sphere with a nominal diameter of 0.2 mm will fall only about one-third faster than a similar sized particle with a shape factor of 0.3; a sphere with a nominal diameter of 4.0 mm falls over 2 1/2 times faster than a particle with SF=0.3. For curves showing temperature effects, correction tables, etc., the reader is referred to (26).

In the absence of better data, the hydraulic size of a particle can be computed from the following (27);

$$W^{3/2} = gd^{3/2}\,(s.g.-1)/11.2\sqrt{\nu} \quad \text{when } 1<Re<30, \; 0.1<d<0.6 \text{ mm} \tag{10}$$

$$W^{1.8} = gd^{1.2}\,(s.g.-1)/4.4\nu^{0.2} \quad \text{when } 30<Re<400, \; 0.6<d<2.0 \text{ mm} \tag{11}$$

$$W = 0.875\sqrt{gd(s.g.-1)} \quad \text{when } Re>400, \; d>2 \text{ mm} \tag{12}$$

Equation (10) is Prandtl's formula for a smooth channel, while equation (12) is the so-called square law.

The transport of solid particles by a fluid stream is an exceedingly complex phenomena and no complete theory which takes into account all of the parameters has yet been formulated. Empirical formulae exist, however, some of which have a fairly wide range of applicability. An expression for the lowest velocity at which solid particles heavier than water still do not settle out onto the bottom

TABLE 3. EFFECT OF SHAPE FACTOR ON HYDRAULIC SIZE (IN CM/SEC)*

Nominal Diameter (mm)	Shape Factors 0.3	0.5	0.7	0.9	Spheres
0.20	1.78	1.94	2.11	2.26	2.43
0.50	4.90	5.63	6.31	7.02	7.68
1.00	8.49	10.10	12.10	14.00	15.60
2.00	12.50	15.50	19.30	23.90	28.60
4.00	17.80	22.40	28.00	35.60	46.90

* Taken from reference 26.

of the pipe or channel has been developed by Knoroz (28) on the basis of numerous experiments carried out under his direction at the All-Union Scientific Research Institute for Hydraulic Engineering. It expresses the velocity in meters per second as;

$$V = 3\left[\sqrt{gd}\ \lg \frac{R}{4d} + W\ p^{1/4} \left(\frac{R}{d}\right)^{0.4}\right] \tag{13}$$

where average values of d and W for the solids mixture are to be used; R is the hydraulic radius; and p is the consistency by weight of the mixture, i.e., in percent the expression for p is:

$$p = \frac{\gamma_m - \gamma}{\gamma_p - \gamma_m} \frac{\gamma_p}{\gamma} \tag{14}$$

where γ is the specific weight of the fluid, γ_p is the specific weight of the particles, and γ_m is the specific weight of the mixture. For a review of this and other Russian work on the flow of a two-phase mixture see (27).

A somewhat simpler expression for the adequate self-cleaning velocity of sewers derived by Camp from experimental findings of Shields as given in (29) is:

$$V = \sqrt{6.4gd\ (s.g.-1)/f} = \frac{1.486}{n} R^{1/6} \sqrt{0.8d(s.g.-1)} \tag{15}$$

where f is the friction factor, n is Manning's roughness coefficient, and all other terms are as previously identified. Using equation (15), for example, it is seen that a velocity of 2 feet per second is required to adequately transport a 0.09 mm particle with a specific gravity of 2.65 and a friction factor of 0.025. By comparison, the fall velocity of such a particle is around 0.2 feet per second.

In summary, the sampling train must be sized so that the smallest opening is large enough to give assurance that plugging or clogging is unlikely in view of the material being sampled. However it is not sufficient to simply make all lines large, which also reduces friction losses, without paying careful attention to the velocity of flow. For a storm or combined sewer application, minimum line sizes of 3/8- to 1/2-inch inside diameter and minimum velocities of 2 to 3 feet per second would appear warranted.

SAMPLE CAPACITY AND PROTECTION ASSESSMENT

For storm and combined sewer applications, discrete sampling is generally desired. This allows characterization of the sewage throughout the time history of the storm event. If the samples are sufficiently large, manual compositing can be performed based on flow records or some other suitable weighting scheme. Although the quantity of sample required will be a function of the subsequent analyses that are to be performed, in general at least 1 quart and preferably 2 quarts will be desired. An additional benefit arises because such relatively large samples are less vulnerable to errors arising from cross-contamination.

A brief look at the different types of composite samples is in order. Any scheme for collecting a composite sample is, in effect, a method for mechanically integrating to obtain average characteristics. Let us consider a given flow rate q(t) and pollutant concentration level k(t) where:

$$q \overset{d}{=} L^3T^{-1} \text{ and } k \overset{d}{=} ML^{-3} \qquad (16)$$

The quantity of flow and pollutant are then:

$$Q = \int q dt \text{ and } P = \int qk dt \qquad (17)$$

where:

$$Q \overset{d}{=} L^3 \text{ and } P \overset{d}{=} M \qquad (18)$$

Let us consider first the simple composite, where a constant volume of fluid is added at evenly spaced time intervals. We will denote such a sample by T_cV_c, meaning time interval between successive aliquots constant and volume of aliquot constant. Let the time duration of the event in question be divided up into n elements and a subscript i be used to denote instantaneous values ($0<i\leq n$). Then the overall concentration of the simple composite sample will be:

$$K = \frac{P}{Q} = \frac{1}{n}\sum_{i=1}^{n} k_i \qquad (19)$$

If one wishes a more representative sample, some type of proportioning must be used. This is equivalent to saying that equation (19) is a very poor scheme for numerical integration, and a higher order method is desirable. There are two fundamental approaches to obtaining better numerical integration given a fixed number of steps. One is to increase the order of the integration scheme to be used; as in going from the trapezoidal rule to Simpson's rule, for instance. The other is to vary the step size in such a way as to lengthen the steps when slopes are changing very slowly and shorten them when slopes change rapidly. Typical of the first approach are the constant time interval, variable volume (T_cV_v) proportional composites. There are two straightforward ways of accomplishing this. One is to let the aliquot volume be proportional to the instantaneous flow rate, i.e.:

$$v_i = Aq_i \tag{20}$$

and the other is to make the aliquot volume proportional to the quantity of flow that has passed since extraction of the last aliquot, i.e.:

$$v_i = B(Q_i - Q_{i-1}) = B\Delta Q_i \tag{21}$$

The respective concentrations of samples are

$$K_A = \frac{\sum_{i=1}^{n} q_i k_i}{\sum_{i=1}^{n} q_i} \text{ and } K_B = \frac{\sum_{i=1}^{n} \Delta Q_i k_i}{\sum_{i=1}^{n} \Delta Q_i} \tag{22}$$

Typical of the second approach is the variable time interval, constant volume (T_vV_c) proportional composite. Here a fixed volume aliquot is taken each time an arbitrary quantity of flow has passed (Q/n), i.e. the time is varied to give a constant ΔQ. The concentration will be:

$$K = \frac{1}{n}\sum_{i=1}^{n} k_i \tag{23}$$

It must be remembered that here the time steps are differing so that comparison of equations (23) and (19) has no meaning.

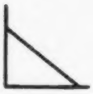
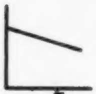
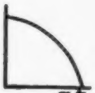
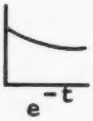
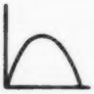
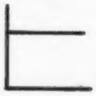
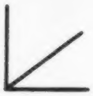
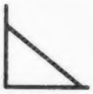
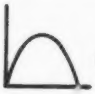
It is instructive to compare these four composite sample schemes with each other. For the purposes of this exercise let us arbitrarily set $n=10$ and normalize time so that $0 \le t \le 1$. We will examine four flow functions; $q=c$, $q=t$, $q=1-t$, and $q=\sin\pi t$. We will also examine five concentration functions; $k=1-t$, $k=1-t/2$, $k=\cos\pi t/2$, $k=e^{-t}$, and $k=\sin\pi t$.

These selections are completely arbitrary (except for simplicity in exact integration), and the curious reader may wish to examine more typical expressions. For a storm event, the combination $q=\sin\pi t$ and $k=e^{-t}$ allows for low volume, highly polluted flow initially, with pollutant concentration falling throughout the event. However the resemblence is qualitative only, and more refined expressions could be used. For each flow/concentration combination, the exact average concentration of the flow was computed (as though the entire flow stream were diverted into a large tank for the duration of the event and then its concentration measured). The ratio of the composite sample concentration to the actual concentration so computed is presented in matrix form in table 4. The four lines in each cell represent the four types of composite samples discussed as indicated in the legend. The best overall composite for the cases examined is the T_cV_v with the volume proportional to the instantaneous flow rate q. The T_cV_v, where the volume is proportional to the flow since the last sample, and the T_vV_c gave very similar results with a slight edge to the former. However, the differences are not large for any case. This brief look at compositing merely scratches the surface, but a more definitive treatment is outside the scope of the present effort. Suffice it to say here that both flow records and a knowledge of the temporal fluctuation of pollutants, as can be obtained from discrete samples, are required in order to choose a "best" compositing scheme for a given installation.

The sample container itself should either be easy to clean or disposable. The cost of cleaning and sterilizing makes disposable containers attractive, especially if bacteriological analyses are to be performed. Although some of today's better plastics are much lighter than glass and can be autoclaved, they are not so easy to clean or inspect for cleanliness. Also the plastics will tend to scratch more easily than glass and, consequently, cleaning a well-used container can become quite a chore. The food packaging industry, especially dairy products, offers a wide assortment of potential disposable sample containers in the larger sizes. Both the 1/2-gallon paper and plastic milk cartons can be considered viable candidates, and their cost in quantity is in the pennys-each range.

The requirements for sample preservation were enumerated in section IV and will not be repeated here. It should be mentioned, however, that if the samples are allowed to become too cold, they may no longer be representative.

TABLE 4. RATIO OF COMPOSITE SAMPLE CONCENTRATION TO ACTUAL CONCENTRATION

CONC k q FLOW	 $1-t$	 $1-\frac{t}{2}$	 $\cos\frac{\pi t}{2}$	 e^{-t}	 $\sin \pi t$
 C	0.90 0.90 0.90 0.90	0.97 0.97 0.97 0.97	0.92 0.92 0.92 0.92	0.95 0.95 0.95 0.95	0.99 0.99 0.99 0.99
 t	1.35 0.90 0.86 0.87	1.09 0.97 0.96 0.96	1.26 0.90 0.87 0.89	1.14 0.97 0.95 0.95	0.99 0.90 0.89 0.97
 1-t	0.68 0.95 0.92 0.92	0.87 0.98 0.97 0.97	0.72 0.98 0.95 0.93	0.82 0.96 0.95 0.95	0.99 1.12 1.09 0.97
 sinπt	0.90 1.01 0.90 0.90	0.97 1.00 0.97 0.97	0.88 1.00 0.92 0.92	0.97 1.00 0.95 0.95	0.80 1.01 0.98 0.97

Line 1. $T_c V_c$ - Simple composite

Line 2. $T_c V_v$ - Volume proportional to flow rate (q)

Line 3. $T_c V_v$ - Volume proportional to flow (Q) since last sample

Line 4. $T_v V_c$ - Time varied to give constant ΔQ

For example destruction of the organisms necessary for the development of BOD may occur or freezing may cause serious changes in the concentration of suspended solids. Light can also affect samples and either a dark storage area or opaque containers would seem desirable. Unless disposable containers are used, however, it will be difficult to inspect an opaque container for cleanliness. Again the paper milk carton is attractive since not only is it relatively opaque, but its top opens completely allowing visual inspection of its contents.

CONTROLS AND POWER ASSESSMENT

The control aspects of some commercial automatic samplers have come under particular criticism as typified by comments in section VIII. It is no simple matter, however, to provide great flexibility in operation of a unit while at the same time avoiding all complexities in its control system. The problem is not only one of component selection but packaging as well. For instance, even though the possibility of immersion may be extremely remote in a particular installation, the corrosive highly-humid atmosphere which will, in all liklihood, be present makes sealing of control elements and electronics desirable in most instances.

The automatic sampler for storm and combined sewer application will, in all liklihood, be used in an intermittent mode; i.e. it will be idle for some period of time and activated to capture a particular meteorological event. If field experience to date is any indication, the greatest need for an improved control element is for an automatic starter. While the sensor is not a part of the sampler proper, its proper function is essential to successful sampler utilization. Although remote rain gages, etc. can be used for sensing elements, one of the most attractive techniques would be to use the liquid height (or its rate of increase) to start a sampling cycle. This will avoid the difficulties associated with different run-off times due to local conditions such as dryness of ground, etc. An additional benefit arising from the use of such a device will be a means of obtaining a measure of flow rate under some conditions by relating the site hydraulics with the flow depth.

One of the attributes essential to the control system of an automatic sampler to be used in a storm and/or combined sewer application is that it be able to withstand power outages and continue its program. Such power interruptions appear to be increasingly common as demand for electricity continues to grow. Although desirable in some instances, the provision of a random interrogate signal to be coupled with a sequence sample mode generates programming problems, especially when coupled with power interrupt possibilities.

Reliability of the control system can dominate the total system reliability. At the same time, this element will, in all liklihood, be the most difficult to repair and calibrate. Furthermore, environmental effects will be the most pronounced in the control system. The power switching function of the control system may be required to deal with multiple switching of inductive loads and must achieve the switching of these loads without the typical damage associated with transfer of energy interruptions.

The above tasks can probably be best executed, in the light of the current electronics state-of-the-art, by a solid state controller element. In addition to higher inherent reliability, such an approach will allow switching of high level loads in a manner that eliminates RFI emissions and destructive results. In addition, the unit should be of modular construction for ease of modification, performance monitoring, fault location, and replacement/repair. Such an approach also lends itself to encapsulation which will minimize environmental effects. Solid state switching eliminates the possibility of burned or welded contacts either of which will cause complete sampler breakdown.

Solid state controllers can be easily designed with sufficient flexibility to accept start commands from a variety of types of remote sensors, telephone circuits, etc.

Low operational current requirements would allow a solid state controller to continue to operate from a battery source during a local power outage. This capability would avoid logic interrupts and attendent loss of data and allow the sampler operation to be restored immediately upon the return of power service.

The foregoing discussion as it relates to problems associated with interruptions in electrical service is of course directed to samplers that rely upon outside power for some aspect of their operation. The need for high sample intake and transport velocities, larger sample lines and capacities, together with the possible requirement for mechanical refrigeration make it unlikely that such a sampler can be totally battery operated today. Although recent break-throughs have resulted in 1 kw dry cell batteries, their cost is prohibitive for this sort of an application. Other approaches to self-contained power such as custom designed wet cell packs, diesel generators, etc., while within the current state-of-the-art, introduce other problems and complexities that must be carefully weighed before serious consideration can be given to their incorporation in an automatic sampler design.

SECTION X

ACKNOWLEDGEMENTS

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SECTION XI

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